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LOCAL HAZARD MITIGATION PLAN

Municipality of



LOCAL HAZARD
MITIGATION PLANS

Protect Through Planning

PROFESSIONAL LICENSED PLANNER CERTIFICATION

As per Act 160-1996, as amended (20 L.P.R.A § 3501 - 20 L.P.R.A § 3515), I _____, who bears Puerto Rico professional planning license number ____, certify that this document has been prepared using the best available sources and is in accordance with the best practices of the planning profession as of _____, 2026. And I certify this herewith my professional seal.

FEMA Approval

This Local Hazard Mitigation Plan for the Municipality of Aguada was approved by FEMA on

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Statement of Funding

This Local Hazard Mitigation Plan (LHMP) for the Municipality of Aguada is funded with a grant given to the Puerto Rico Planning Board by the Central Office for Recovery, Reconstruction and Resiliency. This LHMP was prepared by the consulting firm AtkinsRéalis Caribe, LLP as per the stipulations of contract number 2026-000032.

Language Requirement

In accordance with Presidential Executive Order #14224, the 2026 version of Aguada Local Hazard Mitigation Plan has been prepared in English for submission and consideration of FEMA.

A non-certified translation of the final draft for public review and the final approved LHMP to Spanish was prepared for the benefit of the population that is not English proficient.

Should any discrepancy arise between the English and the Spanish text, the English one shall prevail.

Statement on maps

The maps presented in this document are related to a planning exercise. It is not the intention of these maps to establish any regulatory requirement, procedure or benefit.

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List of Acronyms

ABFE	Advisory Base Flood Elevation
ACS	American Community Survey
AMMED	Municipal Agency for Disaster and Emergency Management, by its Spanish Acronym
BFE	Base Flood Elevation
BLE	Base Flood Engineering
BRIC	Building Resilient Infrastructure and Communities
CDBG-DR	Community Development Block Grant – Disaster Recovery
CDBG-MIT	Community Development Block Grant – Mitigation
CEACC	Committee of Experts and Advisors on Climate Change
COR3	Central Office for Recovery, Reconstruction and Resiliency
CRS	Community Rating Systems
DEM	Digital Elevation Model
DHS	Department of Homeland Security
DNER	Department of Natural and Environmental Resources
DPS	Department of Public Safety
DTOP	Department of Transportation and Public Works
EAL	Expected Annual Loss
EOP	Emergency Operation Plan
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GIS	Geographic Information System

HMGP	Hazard Mitigation Grant Program
HUD	U.S. Department of Housing and Urban Development
IFRC	International Federation of the Red Cross
IRRM	Interim Risk Reduction Measures
LHMP	Local Hazard Mitigation Plan
LUMA	Luma Energy
MHHW	Mean Higher High Water
mph	Miles per hour
MSL	Mean Sea Level
NCEI	National Centers for Environmental Information
NDRF	National Disaster Recovery Framework
NID	National Inventory Dams
NIMS	National Incident Management System
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NTHMP	National Tsunami Hazard Mitigation Program
OMME	Municipal Emergency Management Office
OPM	Municipal Public Works, by its Spanish acronym
PRASA	Puerto Rico Aqueduct and Sewers Authority
PREMB	Puerto Rico Emergency Management Bureau
PREPA	Puerto Rico Electric Power Authority
PRHTA	Puerto Rico Highway and Transportation Authority
PRPB	Puerto Rico Planning Board
PRSN	Puerto Rico Seismic Network
PT	Territorial Plan, by its Spanish acronym
PUT-PR	Puerto Rico Land Use Plan, by its Spanish acronym
SHMO	State Hazard Mitigation Officer
SFLA	Southern Federal Land Assessment
UHI	Urban Heat Island
USACE	United States Army Corps of Engineers
USDA	United State Department of Agriculture
USDOT	United States Department of Transportation
USGS	United States Geological Survey
VSL	Value of Statistical Life

Executive Summary

This document is the 2026 update of the Local Hazard Mitigation Plan (LHMP) for the Municipality of Aguada, Puerto Rico. It is prepared to reduce risks associated with natural hazards and enhance community resilience by identifying hazards, assessing risks, and proposing mitigation strategies. The plan complies with federal regulations, including the Stafford Act and Disaster Mitigation Act of 2000, and incorporates public participation and interagency coordination. It is funded by a grant from the Puerto Rico Planning Board and prepared by AtkinsRéalis Caribe, LLP.

Introduction and Background

The Municipality of Aguada and the Puerto Rico Planning Board are committed to protecting residents by updating the LHMP, which provides a structured approach to hazard mitigation consistent with federal, state, and local policies. The plan identifies natural hazards, evaluates risks, and supports land use planning to achieve sustainability and resilience. It also complies with FEMA requirements to maintain eligibility for federal funding and is regularly updated to reflect evolving conditions.

This plan follows the following objectives

- Identify and evaluate natural hazards threatening the municipality.
- Establish strategies to reduce risks to life, property, and services.
- Promote interagency coordination and community involvement

Public Policy

The plan aligns with federal, Puerto Rico, and municipal policies guiding hazard mitigation and resilience for example.

- The Stafford Act and its Hazard Mitigation Grant Program provide funding for cost-effective mitigation.
- The Disaster Mitigation Act of 2000 requires LHMP adoption for federal funding eligibility.
- The National Flood Insurance Act establishes the NFIP to provide flood insurance and encourages floodplain management.

- FEMA's regulations (44 CFR Part 201) and planning guides outline requirements and procedures for mitigation planning.
- The National Disaster Recovery Framework guides recovery coordination.
- The National Earthquake Hazards Reduction Program and National Incident Management System that support seismic risk reduction and emergency response.

Puerto Rico Policies

- Act No. 161-2009 reforms the permitting system to improve efficiency.
- Act No. 33-2019 mandates mitigation and resilience measures in response to changing weather patterns.
- Act No. 107-2020 (Municipal Code) which gives municipalities some powers for regulating land use.
- The Puerto Rico Land Use Plan (that PUT-PR) classifies land and guides sustainable development.
- The Puerto Rico State Natural Hazard Mitigation Plan (2021) provides a jurisdiction-wide framework.
- The Puerto Rico Mitigation Action Plan (CDBG-DR MIT) directs federal mitigation funds post-hurricanes Irma and María.
- The Aguada LHMP (2020) and Municipal Recovery Plan establishes prior mitigation frameworks and recovery priorities.

Planning Process

The 2026 LHMP update follows FEMA guidelines and includes a Planning Committee with municipal officials, public outreach through meetings and notifications, and stakeholder involvement. Public participation included three community meetings with opportunities for feedback. The plan integrates FEMA Lifelines (Safety and Security, Food, Hydration and Shelter, Health and Medicine, Energy, Communications, Transportation, Hazardous Materials, Water Systems) to prioritize critical services.

Municipal Profile

The Municipality of Aguada is located on the western coast of Puerto Rico and covers approximately 30.21 square miles (78.2 km²). It is bordered by Aguadilla to the north, Moca to the east, Añasco to the south, and Rincón to the west. Aguada is composed of eighteen wards (barrios) and is characterized by a diverse landscape that includes coastal plains, river valleys, extensive hydrographic systems, and progressively higher

terrain toward the southern portion of the municipality. Major water bodies include the Culebrinas River, Guayabo River, and Grande River, which play an important role in local drainage patterns and flood risk. The municipality also contains approximately 10.57 kilometers of coastline, making coastal hazards an important consideration for mitigation planning. These physical characteristics influence exposure to flooding, storm surge, long-term coastal dynamics, landslides, and tropical cyclone impacts

Demographics

According to the 2024 ACS, the Municipality of Aguada has an estimated population of 37,758 residents, composed of 48.87 percent males and 51.13 percent females. The municipality's demographic profile reflects important considerations for hazard mitigation planning, particularly because 40.35 percent of the population is considered socially vulnerable due to being under 19 years of age or over 65 years of age. The age distribution indicates an aging population, with significant growth occurring among older age groups while several younger age cohorts continue to decline. This demographic trend may increase future demand for emergency assistance, evacuation support, healthcare services, and resilience measures targeted at vulnerable populations.

Socioeconomic Conditions

Socioeconomic conditions further influence the municipality's ability to prepare for, respond to, and recover from hazard events. Labor force participation is estimated at 38.8 percent, with an unemployment rate of approximately 5 percent. Major employment sectors include educational services, healthcare and social assistance, retail trade, and professional and administrative services. At the same time, 46.5 percent of the population lives below the poverty level, the median household income is approximately \$21,501, and 56 percent of households earn less than \$25,000 annually. These conditions suggest that a substantial portion of the population may have limited financial resources available for preparedness activities, property improvements, relocation, or disaster recovery.

Housing

Recent development patterns were also evaluated as part of the municipal profile. Between 2020 and 2026, construction activity remained active throughout Aguada, with permits distributed across both developed and rural areas of the municipality. Development has been concentrated primarily within the northern and central

sectors, including Barrio Pueblo, Guaniquilla, Guayabo, and surrounding wards. Understanding where recent growth has occurred helps identify potential future exposure to natural hazards and supports the integration of mitigation considerations into land use planning, infrastructure investments, and development decisions

Critical Infrastructure and FEMA Lifelines

The LHMP assesses municipal infrastructure in alignment with FEMA Lifelines, including safety and security; food, hydration, and shelter; health and medical services; energy; communications; transportation; hazardous materials; and water systems. Critical facilities such as hospitals, police facilities, emergency centers, shelters, and related assets are mapped and evaluated to understand their exposure and role in supporting emergency response and community recovery. This lifeline-based approach helps identify where mitigation investments can protect essential services and reduce cascading impacts during hazard events.

Recent Development

Recent development patterns were also evaluated as part of the municipal profile. Between 2020 and 2026, construction activity remained active throughout Aguada, with permits distributed across both developed and rural areas of the municipality. Development has been concentrated primarily within the northern and central sectors, including Barrio Pueblo, Guaniquilla, Guayabo, and surrounding wards. Understanding where recent growth has occurred helps identify potential future exposure to natural hazards and supports the integration of mitigation considerations into land use planning, infrastructure investments, and development decisions.

Hazard Profiles and Risk Assessment

The LHMP evaluates eleven hazards: earthquake, landslides, tsunامي, flooding, tropical cyclones and extreme winds, storm surge, extreme heat, drought, wildfire, long-term coastal dynamics, and pandemic/epidemic. Each hazard is evaluated in terms of its characteristics, affected areas, magnitude, past occurrences, future probability, potential losses, impacts on Community Lifelines, social vulnerability, natural and cultural resources, and future conditions.

Earthquake

Earthquake risk is a significant concern for Aguada because Puerto Rico is located

near the boundary of the North American and Caribbean tectonic plates and is influenced by several active seismic zones. The assessment considers earthquake magnitude, intensity, spectral acceleration, spectral displacement, and ground motion as indicators of potential impacts. The highest spectral acceleration values and the greatest concentration of exposed population and critical facilities occur primarily within the northern and more urbanized portions of the municipality.

The estimated annual earthquake loss is approximately \$9.25 million, including about \$5.13 million in building losses and \$4.13 million in population-equivalent losses. Earthquakes may affect all Community Lifelines by damaging buildings, transportation routes, power and water systems, communications infrastructure, healthcare facilities, and public-safety operations. Social vulnerability may be heightened by poverty, limited household resources, disabilities, lack of transportation, and the needs of older residents during response and recovery.

The continuing South-Southwest Puerto Rico seismic sequence demonstrates that earthquake hazards remain an ongoing concern. Because earthquakes cannot be predicted precisely, mitigation priorities include structural resilience, compliance with seismic design standards, protection of critical facilities, continuity-of-operations planning, emergency preparedness, and public education.

Landslides

Landslides in Aguada are primarily triggered by intense rainfall and are influenced by slope conditions, soil characteristics, geology, land cover, drainage patterns, and human activity. The areas of highest landslide susceptibility are concentrated in the southern and southeastern portions of Aguada, particularly within Marías, Naranjo, Cerro Gordo, Atalaya, Lagunas, and portions of Mamey, where steeper terrain dominates the landscape.

Although monetary losses could not be calculated because no standardized loss model was available, landslides may obstruct roads, isolate communities, damage utility systems, and restrict access to emergency services. Transportation is considered the most vulnerable Community Lifeline because several roads connecting the northern and urban areas with the southern and southeastern wards cross landslide-susceptible terrain.

Reported landslides following Hurricane María were concentrated primarily in the municipality's southern and southeastern wards. Because rainfall-induced slope

failures are expected to continue, landslides remain an important consideration for land use controls, slope stabilization, drainage improvements, infrastructure maintenance, emergency access, and future development decisions.

Tsunami

Tsunamis are rapid-onset coastal hazards generally caused by undersea earthquakes, although submarine landslides and volcanic activity may also generate them. While they travel quickly and remain relatively low in deep water, their speed decreases and wave height rise sharply near shore, producing destructive flooding, strong currents, erosion, and debris impacts. Natural warning signs may include sudden sea withdrawal or rise and a loud ocean roar; because the hazard cannot be prevented, effective risk reduction depends on alert systems, evacuation planning, public education, drills, and coordinated initiatives such as the National Tsunami Hazard Mitigation Program and NOAA's TsunamiReady Program.

In Aguada, tsunami inundation is concentrated primarily along the northern coastal plain, including portions of Espinar, Carrizal, Guaniquilla, Grande River from Añasco, Guayabo, and Barrio Pueblo. The modeled impact area encompasses approximately 1.01 square miles and includes an estimated 3,974 residents and approximately \$665.7 million in exposed building value. The estimated annual tsunami loss is approximately \$532.

Puerto Rico's historical record, including the destructive tsunamis of 1867, 1918, and 1946, demonstrates the hazard's potential for fatalities, displacement, structural damage, and rapid inland flooding. Although tsunamis are infrequent and cannot be predicted precisely, the island's surrounding offshore seismic zones create a continuing possibility that a strong earthquake could generate another event, reinforcing the importance of Aguada's evacuation map and TsunamiReady certification.

Tsunami consequences can cascade across community lifelines by disrupting emergency services, housing, healthcare, power, communications, transportation, ports, and water and wastewater systems, while also damaging coastal ecosystems and cultural resources. National Risk Index data identify a small, exposed area and population but substantial total exposure value, even though modeled expected annual losses are reported as zero. Nevertheless, lower-income residents, older adults, people with disabilities, households without reliable transportation, and socially isolated populations may face greater evacuation and recovery challenges, while the

scarcity of approved construction permits within the modeled impact area from 2020 through 2026 suggests that recent development has generally avoided the highest-risk zone.

Flooding

Flooding in Aguada includes both general flooding and flash flooding, most often associated with tropical weather systems and intense rainfall events. Flood hazard areas are concentrated primarily within the municipality's northern portion and along the Culebrinas River, Guayabo River, Grande River from Añasco, Caño Madre Vieja, and associated tributaries and drainage corridors.

The FEMA National Risk Index identifies approximately 1.52 square miles of exposed area, approximately 4,298 exposed residents, and more than \$677 million in exposed building value. The estimated annual flood loss is approximately \$10.03 million. Separate Hazus modeling estimates approximately \$117.4 million in losses for a 1-percent annual-chance flood and \$182.3 million for a 0.2-percent annual-chance flood.

Social vulnerability to flooding is especially high among low-income residents, mobility-limited populations, and households with limited access to transportation or financial resources. These conditions can affect the ability of residents to evacuate, protect property, obtain insurance, or recover after flood events. As a result, flood mitigation remains a central priority for reducing losses, protecting public health, and strengthening community resilience.

Tropical Cyclones/Extreme Winds

Tropical cyclones and extreme wind events represent some of the most frequent and damaging hazards affecting Aguada. These events include tropical depressions, tropical storms, hurricanes, and localized tornadoes and can range from tropical storms to Category 5 hurricanes, as classified by the Saffir-Simpson Hurricane Wind Scale. The entire municipality is considered exposed to their impact.

Aguada has experienced impacts from major tropical cyclones affecting Puerto Rico, including widespread wind damage, utility interruptions, infrastructure impacts, and extended recovery needs. Three tornadoes were also documented in Aguada in 2002, 2013, and 2023, confirming that localized extreme-wind events should remain part of the municipality's hazard profile.

The FEMA National Risk Index estimates approximately \$4.96 billion in exposed building value and an annual expected loss of approximately \$21.92 million from tropical cyclones and extreme winds. Because tropical cyclones can affect all FEMA Lifelines, including energy, communications, transportation, safety and security, health and medical services, food and shelter, water systems, and hazardous materials, their impacts can cascade across the community. Social vulnerability is considered widespread due to the municipality-wide exposure of residents, housing, infrastructure, and essential services.

Storm Surge

Storm surge is the abnormal inland movement of seawater caused primarily by the strong winds and low atmospheric pressure associated with hurricanes and tropical storms. Its magnitude depends on storm intensity, size, speed, angle of approach, coastal configuration, topography, and bathymetry, with the most severe impacts occurring when surge coincides with high tide and strong wave action.

In Aguada, modeled storm surge exposure is concentrated along the northern coastal zone, primarily within Carrizal and Espinar, with smaller affected areas extending into portions of Guaniquilla and Guanábano. The Category 5 scenario extends farther inland than the Category 1 scenario, although most of the municipality remains outside the modeled storm surge areas.

Storm surge may affect coastal roads, residences, public facilities, utilities, emergency access routes, recreational resources, beaches, and sensitive coastal habitats. Although the directly exposed population and recent development are geographically limited, residents in low-lying coastal areas may face displacement, interruptions to essential services, restricted evacuation access, erosion, and saltwater intrusion. Impacts may fall disproportionately on low-income households, older adults, residents with limited transportation or healthcare access, and communities with fewer recovery resources. Storm surge can also damage agriculture through crop losses and soil salinization, degrade wetlands, mangroves, beaches, fisheries, and water quality, and threaten cultural resources and coastal community. Future planning should therefore integrate hazard mitigation, Community Lifeline stabilization, protection of natural and cultural resources, equitable recovery, and measures that reduce hazardous-material releases and long-term economic disruption.

Extreme Heat

Extreme heat is defined as prolonged periods of temperatures above 90 degrees Fahrenheit combined with high humidity, conditions that can increase health risks and place stress on infrastructure systems. Developed areas may experience higher temperatures due to the urban heat island effect, increasing exposure for residents in more urbanized portions of the municipality.

Extreme heat can affect public health, energy demand, transportation systems, communications, and other essential services. Older adults and other vulnerable populations may face elevated risk, particularly when risk perception is low or when access to cooling, medical care, or reliable transportation is limited. Health impacts may include heat-related illness and increased mortality among sensitive populations.

Future projections indicate that temperatures and the frequency of extreme heat events are expected to rise, reinforcing the need for mitigation actions such as public outreach, urban greening, shade improvements, cooling strategies, and infrastructure adaptation. These measures can reduce exposure, improve preparedness, and protect vulnerable residents during periods of excessive heat.

Drought

Drought in Aguada is characterized by prolonged precipitation deficits that may reduce water availability, affect agricultural activity, increase operational costs, and disrupt essential community services. This hazard may occur as a meteorological, agricultural, hydrological, or socioeconomic drought. All these types of droughts can impact water availability and community functions.

Drought conditions can lead to water rationing, affect economic and agricultural activities, increase stress on households and businesses, and contribute to increased wildfire potential. Previous drought events have been documented through federal declarations, demonstrating that the hazard has affected Puerto Rico in the past and remains relevant to local mitigation planning.

Future drought frequency is expected to increase, reinforcing the need to strengthen water conservation, emergency water supply planning, infrastructure resilience, public awareness, and coordination with regional water providers. Social vulnerability is particularly important for elderly residents and low-income households, which may

have fewer resources to adapt to water interruptions, higher utility costs, or related public health and economic impacts.

Wildfire

Wildfire consists of uncontrolled fires that may occur in vegetated or dry forest areas and may be intensified by drought conditions and long-term climate trends. Wildfire behavior may include surface fires, crown fires, ground fires, and interface fires where developed areas meet wildland vegetation, creating potential risks to residents, structures, infrastructure, and natural resources.

Aguada has historically experienced a relatively low incidence of wildfire; however, some areas near municipal borders present higher potential risk. Wildfires can threaten natural ecosystems, cultural resources, public infrastructure, transportation access, and nearby communities. Puerto Rico Fire Bureau records identify multiple wildfire incidents in Aguada during 2024. Wildfire risk may increase as temperatures rise, drought conditions become more frequent, vegetation becomes stressed, and human activity continues near vegetated areas. This hazard should continue to be monitored as part of the municipality's risk profile.

Social vulnerability to wildfire is associated with poverty, disability prevalence, limited evacuation capacity, and constraints on household preparedness. Although current wildfire incidence is comparatively low, future risk may increase as dry conditions become more frequent and vegetation stress intensifies. Mitigation measures such as public education, defensible space practices, vegetation management, emergency access improvements, and interagency coordination can reduce potential impacts.

Long Term Coastal Dynamics

Long-term coastal dynamics are the gradual processes that reshape coastlines through erosion, accretion, sediment movement, and variations in mean sea level. Unlike isolated storm impacts, these processes unfold over years or decades and progressively alter shoreline position, coastal stability, and exposure to flooding and wave action. Their combined effects can reduce beach width, weaken dunes and other natural buffers, and cause the shoreline to migrate inland, making them an important consideration in hazard mitigation, land-use planning, and infrastructure investment.

Aguada has approximately 10.57 kilometers of coastline, of which approximately 9.86

kilometers, or 93 percent, consists of beaches. Following Hurricane María, erosion was observed along approximately 44 percent of the municipality's beach coastline. Approximately ten months later, 81 percent of the beach coastline showed accretion, although landward beach migration was identified as approximately 2.98 kilometers and shoreline-waterline migration along approximately 1.72 kilometers. These findings show that post-storm recovery was substantial but spatially uneven and did not eliminate long-term shoreline vulnerability.

Coastal erosion may occur episodically during major storms or chronically through persistent sediment deficits, rising water levels, land subsidence, altered river sediment delivery, coastal development, and damage to natural protective systems. Accretion may temporarily or persistently widen beaches and strengthen dunes, but it is not uniform or necessarily permanent and may reflect sediment transferred from another shoreline segment. Human interventions, including coastal structures, dredging, development, and beach nourishment, can modify both erosion and accretion patterns and may create benefits in one area while increasing vulnerability elsewhere.

NOAA tide-gauge records cited in the Plan indicate relative sea-level trends of approximately 2.06 millimeters per year at Magueyes Island and 2.16 millimeters per year at San Juan through 2025. Although these stations are not located in Aguada, they provide regional evidence of increasing relative sea level around Puerto Rico.

These dynamics threaten multiple Community Lifelines, including emergency services, water and wastewater systems, healthcare access, energy, communications, transportation, and hazardous-material facilities. They also disproportionately affect low-income households, renters, older adults, people with disabilities or chronic health conditions, and communities dependent on coastal livelihoods, while endangering beaches, dunes, wetlands, mangroves, coral reefs, historic sites, and other cultural resources. Because future coastal change in Aguada is considered highly likely, the document supports sustained shoreline monitoring, nature-based solutions, land-use controls, resilient infrastructure siting, adaptive shoreline management, and mitigation actions that protect essential services and vulnerable populations.

Pandemic/Epidemic

Pandemic and epidemic hazards include localized disease outbreaks as well as widespread events that can extend across regions, nations, or globally. For planning purposes, the entire municipality is considered vulnerable because infectious disease

impacts can affect residents, institutions, workplaces, schools, healthcare providers, and essential services throughout Aguada.

Puerto Rico has experienced several historic outbreaks, including cholera in 1855, measles in 1917, the Spanish Flu in 1918, polio in 1960, as well as, dengue, chikungunya, Zika, and COVID-19 in recent years. The COVID-19 pandemic produced significant health, economic, and social impacts locally and illustrated how disease events can disrupt normal community functions, increase demand for public health services, and affect vulnerable populations.

During pandemic and epidemic events, the healthcare lifeline is typically the most directly affected; however, other FEMA Lifelines may also experience disruptions, including communications, transportation, food supply, shelter operations, public safety, and continuity of government functions. Future pandemic risk remains elevated due to changing environmental conditions, population characteristics, travel patterns, and the continued emergence of infectious diseases. Mitigation and preparedness efforts should therefore emphasize public health coordination, risk communication, continuity planning, support for vulnerable populations, and sustained emergency management capacity.

Hazard Prioritization

The Planning Committee used the results of the hazard profiles and risk assessment to establish mitigation priorities for the Municipality of Aguada. Based on the hazard assessment and planning committee evaluation, flooding, landslides, tropical cyclones/extreme winds, drought, and long-term coastal dynamics were identified as high-priority hazards. Earthquakes, tsunamis, extreme heat, wildfire, and pandemic/epidemic hazards were classified as medium priority, while storm surge was identified as a low-priority hazard. The prioritization process considered exposure, potential impacts to people and property, effects on critical infrastructure and FEMA Lifelines, historical occurrences, and the needs of socially vulnerable populations.

Municipal Capabilities

The LHMP is supported by a range of planning mechanisms, regulatory frameworks, and municipal capacities that guide land use, permitting, floodplain management, infrastructure investment, emergency response, and long-term resilience. These include the Joint Regulation for Permits, the Special Flood Hazard Areas Regulation, the Puerto Rico Building Code, the Stormwater Systems Regulation, the Aguada Territorial

Plan, and the Aguada Emergency Operation Plan. The municipality also participates in the National Flood Insurance Program and complies with the Clean Water Act's NPDES program. In addition, the plan recognizes the value of green infrastructure and nature-based solutions for stormwater management, while the Four-Year Investment Program (PICA) serves as a tool to align public investment with hazard mitigation priorities.

Aguada's technical and administrative capacity is supported by municipal offices with responsibilities related to planning, land use, emergency management, and federal programs. These include a staffed Planning and Land Use Office, Emergency Management Office, and Federal Programs Office, with engineering and specialized technical expertise procured as needed. The municipality's financial capacity is strengthened by positive fund balances and access to federal funding sources, including FEMA's Hazard Mitigation Grant Program (HMGP), Flood Mitigation Assistance (FMA), Building Resilient Infrastructure and Communities (BRIC), and HUD's CDBG-DR and CDBG-MIT programs.

Public outreach and capacity development are also central components of the LHMP. The municipality uses social media, printed materials, and community meetings to inform residents, gather input, and promote public participation in the mitigation planning process. Capacity-building efforts include staff training and collaboration with academic institutions, supporting the municipality's ability to implement mitigation actions and strengthen institutional knowledge. The plan emphasizes clear, inclusive, and accessible communication to improve hazard awareness, encourage preparedness, and increase community participation.

Mitigation Action Plan

The Mitigation Action Plan establishes goals, objectives, and actions intended to reduce hazard impacts on people, property, infrastructure, essential services, and natural and cultural resources. The municipality's objectives include reducing disaster impacts, strengthening its capacity to implement and maintain mitigation programs, increasing public awareness, improving emergency preparedness and recovery coordination, and supporting the replacement or reconstruction of vulnerable bridges.

Mitigation strategies are organized into local planning and regulation, property protection, structural improvements, natural-resource protection, emergency services, and education and awareness. The actions address priorities such as flood-risk reduction, drainage improvements, bridge and roadway resilience, tsunami

evacuation, coastal protection, extreme-heat response, wildfire preparedness, backup energy, water conservation, public warning systems, and community education. Each retained action identifies its applicable hazard, priority, responsible entity, potential funding source, implementation term, and current status.

Overall, the 2026 Aguada LHMP update integrates hazard assessments, policy frameworks, municipal capabilities, community input, and actionable mitigation strategies into a comprehensive planning tool. Through this integrated approach, the municipality seeks to reduce risk, protect essential services, guide future investments, and strengthen resilience to natural hazards and public health emergencies over the coming year.

1. Introduction and Background

The Municipality of Aguada and the Puerto Rico Planning Board (PRPB) are dedicated to protecting the well-being of Puerto Ricans by fostering cultural, social, and economic growth while prioritizing public health and safety. In this effort, the Municipality and the PRPB have agreed on a joint effort to update the Municipality's Local Hazard Mitigation Plan (LHMP). The LHMP provides a structured and comprehensive approach to reducing risks associated with natural hazards and strengthening overall community resilience. In recent years, Aguada has faced considerable impacts from natural disasters, emphasizing the urgent need for proactive actions to reduce vulnerabilities and safeguard critical infrastructure. These experiences highlight the importance of implementing a coordinated and systematic hazard mitigation strategy that is consistent with federal, state, and local policies.

An LHMP identifies and evaluates potential natural hazards and defines actions designed to reduce or eliminate risks to people, property, and the environment. The plan supports the municipality's land use planning efforts by establishing measures that assist Aguada in achieving its long-term sustainability and resilience objectives.

This LHMP complies with the requirements set forth by the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) and the federal regulations derived from it. Under this legislation, local governments in states and territories are required to develop and formally adopt a hazard mitigation plan as a condition for eligibility to receive certain types of funding administered by the Federal Emergency Management Agency (FEMA).

Risk mitigation plays a critical role in guiding future development and enhancing existing municipal infrastructure. To ensure an effective mitigation strategy, the LHMP is regularly updated to reassess natural hazards that may threaten the lives and property of residents and to incorporate appropriate and responsive mitigation measures.

This document represents the second revision of the LHMP for the Municipality of Aguada. The original plan received FEMA approval in 2013, followed by the first update in November 2020. This 2026 update reflects evolving conditions and circumstances that have influenced the municipality over the past five years and incorporates newly

enacted laws, programs, and regulatory requirements. Through this update, Aguada aims to preserve its eligibility for federal mitigation funding prior to future catastrophic events and to present a strengthened plan aligned with current standards and best practices.

The development of this plan was conducted through a coordinated process that incorporated input from state and local agencies, non-governmental organizations, and the public. The overarching goal is to enhance the municipality's capacity to anticipate, reduce, and effectively respond to natural hazards that may affect its jurisdiction.

The primary objectives of the LHMP are to:

- Identify and evaluate natural hazards that pose risks to the municipality.
- Establish strategies and actions to reduce or eliminate long-term threats to life, property, and critical services.
- Encourage interagency coordination and promote community involvement in disaster preparedness and mitigation initiatives.

1.1 Applicable Public Policies

This section outlines the relevant federal, state and municipal public policies that guide the development of the 2026 Aguada LHMP. The overview provided is not intended to be comprehensive. Additional public policies are referenced throughout the document, particularly in Section 4.18.

1.1.1 Federal Policies

The following federal policies establish the framework for hazard mitigation planning and resilience efforts.

1.1.1.1 Federal Laws

Stafford Act and Disaster Mitigation Act of 2000

The Stafford Act is primarily aimed at reducing loss of life and property, alleviating human suffering, minimizing economic impacts, and lowering the costs associated with disaster assistance. In 1988, Congress amended the Act to create the Hazard

Mitigation Grant Program (HMGP), which became the principal source of federal mitigation funding following a disaster declaration by the President of the United States. Through this program, funds are made available to states and territories to implement cost-effective measures that reduce the risk of damage and losses from future hazard events.

Disaster Mitigation Act of 2000

Enacted on October 30, 2000, the Disaster Mitigation Act of 2000 (DMA 2000) further amended the Stafford Act to enhance disaster planning, response, and recovery at all levels of government. This legislation establishes eligibility requirements for municipalities to access federal mitigation funding, including the preparation and adoption of a Local Hazard Mitigation Plan (LHMP). A LHMP demonstrates a jurisdiction's commitment to reducing risks associated with natural hazards and serves as a decision-making tool for implementing preventive and mitigation actions. It also provides a framework for the State to deliver technical assistance and establish funding priorities.

In accordance with DMA 2000 requirements, this LHMP is comprehensive and coordinated, incorporating the participation of state, local, and regional agencies, non-governmental organizations, and members of the public.

National Flood Insurance Act

The National Flood Insurance Act established the National Flood Insurance Program (NFIP) to provide affordable flood insurance coverage to homeowners, businesses, and renters located in flood-prone areas. The program was designed to reduce the financial burden on individuals and the federal government in the aftermath of flood-related disasters.

The Act also encourages participating communities to adopt and enforce minimum floodplain management standards aimed at reducing future flood risks. Communities that comply with these requirements become eligible for NFIP benefits and programs. Access to flood insurance enables property owners to recover more rapidly following flood events without relying solely on federal disaster assistance. Supporting legislation, such as the Flood Disaster Protection Act of 1973, further requires federally regulated lenders to mandate flood insurance coverage for properties located in high-risk flood zones and financed through federally backed mortgages.

The Federal Emergency Management Agency (FEMA) has recognized the Municipality as part of the region that is within the PRPB's coverage within the National Flood Insurance Program. The municipality can request updates and amendments to flood hazard maps utilized by the NFIP through the PRPB.

Additionally, through participation in the Flood Mitigation Assistance Program, the municipality has identified specific mitigation strategies to reduce flood-related risks. Funding has also been allocated for the acquisition of structures located in high-risk flood areas as part of ongoing efforts to decrease vulnerability and exposure to future flood events.

1.1.1.2 Federal Regulations

Mitigation Planning – 44 CFR Part 201

This section of the Code of Federal Regulations describes the rules and procedures governing hazard mitigation planning as mandated under the Stafford Act. It outlines the requirements for the preparation and adoption of mitigation plans, which serve as the primary tool for reducing risks posed by natural hazards at the local level. Additionally, this section establishes the policies and planning processes that guide hazard mitigation efforts, underscoring the role of mitigation plans in directing the effective allocation of resources for disaster risk reduction.

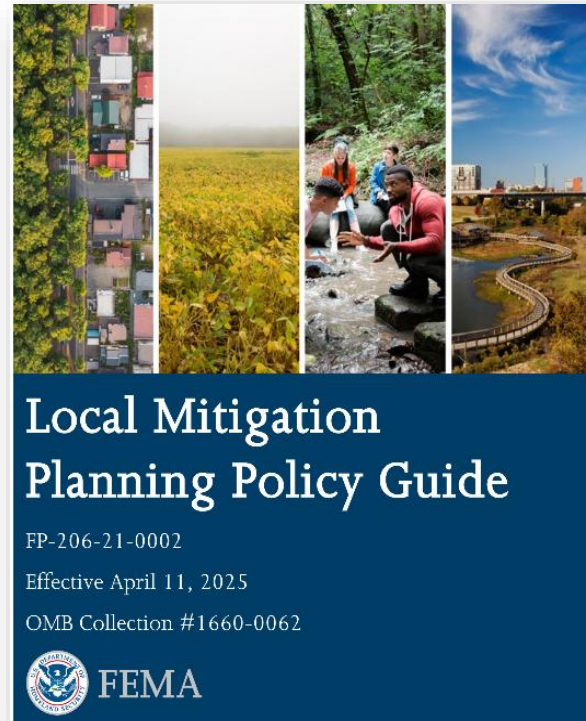
FEMA Local Hazard Mitigation Planning Guide

The Local Hazard Mitigation Planning Policy Guide published by FEMA establishes the official framework and guidance that local governments are required to follow when preparing, reviewing, and updating their Local Hazard Mitigation Plans (LHMPs). This guidance is designed to ensure compliance with the requirements set forth in the

Code of Federal Regulations (44 CFR Part 201). The policy guide emphasizes data-driven planning tailored to local capacities, while prioritizing equity and inclusive stakeholder participation. It encourages communities to integrate hazard mitigation into broader planning and decision-making processes, thereby strengthening long-term resilience and reducing vulnerability to natural hazards (FEMA, Local Mitigation Planning Policy Guide, 2025).

The guide identifies the essential components that every mitigation plan is required to address. In addition, it provides practical resources such as resolution templates, checklists, and plan review criteria to support local governments throughout the planning process. The guide also explains FEMA's plan review and approval process, which may result in full approval, conditional approval pending formal adoption, or return of the plan for revisions and corrections.

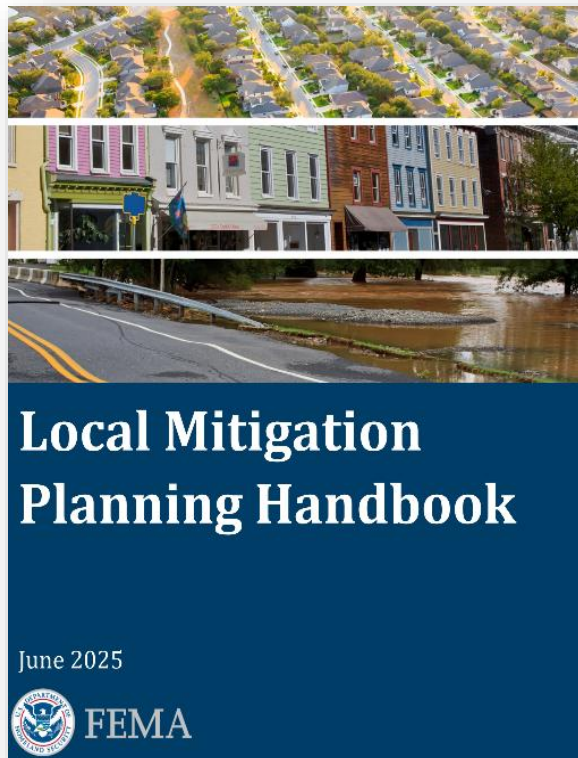
Figure 1. Cover of FEMA's Local Mitigation Planning Policy Guide



Local Mitigation Planning Handbook

The Local Mitigation Planning Handbook is a resource developed by FEMA to assist local governments, including municipalities and special districts, in the development or update of their Local Hazard Mitigation Plans. This handbook serves as a companion

Figure 2. Cover of FEMA's Local Mitigation Planning Handbook



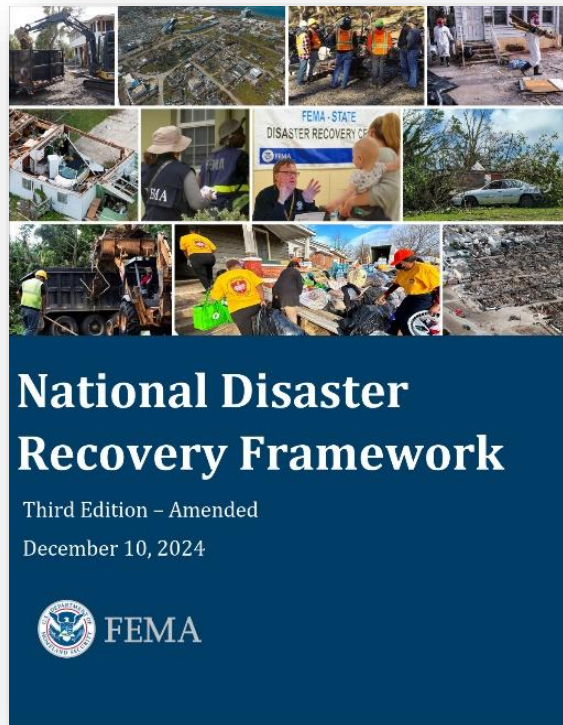
to FEMA's mitigation planning policy guidance and offers a detailed, step-by-step methodology for complying with the requirements outlined in Title 44 of the Code of Federal Regulations, Part 201.

The primary purpose of the handbook is to support communities in identifying the natural hazards they face, evaluating institutional and administrative capabilities, and formulating effective strategies to reduce disaster-related impacts (FEMA, 2025). Ultimately, the handbook promotes the creation of safer and more resilient communities that are better prepared to anticipate, withstand, and recover from adverse events.

National Disaster Recovery Framework

The National Disaster Recovery Framework (NDRF) is a guide created by FEMA in the United States that establishes how recovery should be organized and coordinated after a disaster. Its main objective is to help affected communities rebuild in a stronger, more equitable, and more resilient way, involving all levels of government—local, state, tribal, territorial, and federal—along with private and community organizations.

Figure 3. National Disaster Recovery Framework



This framework promotes recovery that not only restores what was lost but also improves pre-disaster conditions. To achieve this, the NDRF defines guiding principles, specific roles for the actors involved, and coordination structures that facilitate collaboration among agencies. It also emphasizes the importance of planning before a disaster occurs and ensuring that recovery goals are defined by the affected communities themselves.

National Flood Insurance Program

The National Flood Insurance Program (NFIP), administered by FEMA, provides affordable flood insurance coverage to property owners, renters, and businesses while encouraging effective floodplain management practices to

reduce future flood risks. Established in 1968, the NFIP supports communities in minimizing flood-related losses by requiring the adoption and enforcement of local floodplain management regulations. The program also offers insurance coverage for both structures and their contents in more than 22,000 participating communities nationwide.

Because most standard homeowners' insurance policies do not cover flood damage, the NFIP plays a critical role in protecting lives and property while reducing long-term disaster recovery costs. Additional information regarding the Municipality of Aguada's participation in the NFIP is provided in Section 6.5 of this plan.

National Earthquake Hazards Reduction Program

The National Earthquake Hazards Reduction Program (NEHRP) was established under the Earthquake Hazards Reduction Act of 1977 to advance the development, dissemination, and application of knowledge, tools, and practices that reduce risks associated with seismic events. This objective is achieved through coordinated, multidisciplinary, and interagency collaboration among NEHRP's participating federal

agencies and partners, including local jurisdictions such as the Municipality of Aguada.

The National Institute of Standards and Technology (NIST), within the U.S. Department of Commerce, serves as the lead agency for NEHRP. The program is further supported by three cooperating federal agencies: the Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), and the United States Geological Survey (USGS). Each agency contributes expertise and complementary activities related to research, preparedness, mitigation, and public safety.

National Incident Management System

The National Incident Management System (NIMS) is a standardized framework developed by the U.S. Department of Homeland Security and administered by FEMA to guide incident management across the nation. Its purpose is to enable effective coordination and cooperation among governmental agencies, private sector organizations, and community-based entities at all jurisdictional levels during the prevention, preparedness, response, and recovery phases of emergencies and disasters.

NIMS establishes a common organizational structure, terminology, and set of processes to ensure seamless coordination regardless of the incident's type, size, or complexity. Core components of the system include resource management, interoperable communications, ongoing preparedness activities, and the Incident Command System (ICS), which defines clear roles, responsibilities, and command structures during emergency operations.

Implementation of NIMS is also a prerequisite for jurisdictions seeking access to certain federal preparedness and response funding. By adopting NIMS, jurisdictions enhance operational efficiency, reduce duplication of efforts, and promote the effective and coordinated use of available resources.

1.1.2 Government of Puerto Rico Policies

The following Government of Puerto Rico policies provide guidance for the development and implementation of the 2026 Aguada LHMP.

1.1.2.1 *Puerto Rico Laws*

Act No. 161–2009, as Amended

Act No. 161–2009, known as the *Puerto Rico Permits Reform Act*, establishes a modern legal and administrative framework designed to comprehensively restructure the Commonwealth’s permitting system. The primary goal of the Act is to create a transparent, efficient, and streamlined process for the submission, evaluation, approval, or denial of permits issued by the Government of Puerto Rico.

To accomplish this objective, the law created the Office of Permits Management (OPM), consolidating permitting responsibilities that were previously distributed across multiple agencies. This centralization reduced procedural delays and improved consistency in the application of permitting standards. The Act also introduced specialized roles—including Authorized Professionals, Permit Managers, Service Representatives, and Permit Officers—each with defined responsibilities intended to expedite reviews and professionalize the permitting process.

A further objective of Act No. 161–2009 is to enhance oversight, accountability, and transparency within the permitting system. By strengthening internal controls and standardizing procedures, the Act seeks to ensure compliance while reducing administrative inefficiencies.

From a public policy perspective, the Act aims to promote economic development while safeguarding environmental protection. Legislative intent emphasizes that an efficient permitting system is essential to attract investment, encourage construction activity, support long-term job creation, and eliminate bureaucratic barriers that previously hindered economic growth. Analyses of the Act also highlight its role in centralizing governmental functions and implementing an Integrated Permitting System to reduce fragmentation, improve interagency coordination, and ensure regulatory uniformity throughout Puerto Rico.

Act No. 33–2019, as Amended

Act No. 33–2019 establishes the public policy of the Government of Puerto Rico regarding mitigation, adaptation, and resilience in response to observed variations in temperature and precipitation patterns. The legislation formally recognizes the need for integrated governmental action, including at the municipal level, to address the impacts of environmental instability.

This Act calls for the incorporation of concrete mitigation, adaptation, and resilience measures into territorial and land use planning instruments. By doing so, it promotes a proactive approach that strengthens communities' capacity to withstand environmental stressors and reduces long-term risks to public safety, infrastructure, and natural resources.

Act No. 107-2020, as Amended

Act No. 107-2020, as amended, known as the *Puerto Rico Municipal Code*, significantly expands the authority, responsibilities, and operational autonomy of municipal governments. The Code promotes local self-governance and enhances municipalities' capacity to manage their own affairs, including disaster preparedness and risk reduction.

Among the responsibilities granted to municipalities is the authority to design and implement programs and measures to prevent, respond to, and recover from emergencies, natural disasters, catastrophic accidents, and other hazardous events. This expanded role reinforces the importance of municipal governments in protecting public safety and community well-being.

The Municipal Code also grants municipalities that qualify enhanced autonomy over land use regulation within their jurisdictions. This authority includes the application of tools such as the transfer of development rights and the evaluation and issuance of construction permits, enabling municipalities to incorporate hazard mitigation principles directly into development decisions. These powers are essential for reducing exposure to natural hazards and safeguarding lives and property. Overall, the Municipal Code recognizes territorial planning as a critical instrument for risk mitigation and establishes a legal framework that enables municipalities to take proactive, locally tailored actions to protect their communities from natural hazards and other adverse events.

1.1.2.2 Puerto Rico Regulations

Puerto Rico Land Use Plan (PUT-PR by its Spanish acronym) - 2015

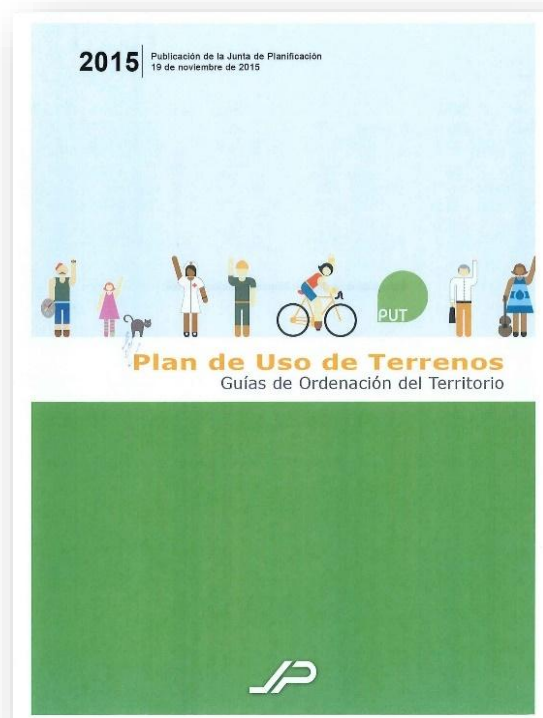
In compliance with Act No. 550-2004, as amended, the Puerto Rico Land Use Plan (PUT, by its Spanish acronym) constitutes the primary territorial planning instrument prepared by the Puerto Rico Planning Board. The Plan is intended to direct land use,

development, and conservation activities throughout the island in a coordinated, sustainable, and resilient manner, guided by a long-term planning horizon of ten (10) years (PRPB, 2015).

One of the primary functions of the Puerto Rico Land Use Plan (PUT) is to classify land throughout the Commonwealth into specific land use categories. Land classification serves as a land administration framework that establishes the types of zoning districts and allowable uses that may be applied to individual parcels. Under the PUT, land is classified according to the following scheme:

- Urban Land (SU, by its Spanish acronym): This category includes areas that are already developed and served by the necessary infrastructure and public services.
- Land for Development: This classification applies to land identified as suitable for future development and is subdivided into two categories:
 - Programmed Development Land (SUP, by its Spanish acronym): Land scheduled for development under established programs or plans.
 - Non-Programmed Development Land (SUNP, by its Spanish acronym): Land available for development that has not yet been assigned to a specific development program.
- Rustic Land: Rustic lands are designated for protection, conservation, or limited use due to their environmental, agricultural, or ecological value. This classification is further subdivided into:
 - Common Rustic Land (SRC, by its Spanish acronym): Areas suitable for limited, low-intensity uses.
 - Specially Protected Rustic Land (SREP, by its Spanish acronym): Areas subject to heightened protection due to their environmental, natural, or cultural significance.

Figure 4. Puerto Rico PUT Coversheet



The PUT-PR aims to coordinate and harmonize land use planning efforts among state agencies and municipalities. It serves as the foundation for the preparation of municipal Land Use Plans (*Planes de Ordenación Territorial*, POT, by its Spanish acronym), which are adopted for an eight-year planning period (PRPB, 2015).

Currently, the PUT-PR is in the process of being updated for the 2026 -2036 planning cycle. This revision will incorporate robust citizen participation, clearly defined compliance and performance metrics, and an inclusive planning approach that integrates economic development, green infrastructure, sustainable transportation systems, and the conservation of natural resources.

Puerto Rico State Natural Hazard Mitigation Plan (2026)

Just as with the requirements applicable to local jurisdictions, the Stafford Act requires states and territories to develop a hazard mitigation plan that covers their entire jurisdiction. In the case of Puerto Rico, the most recent State Hazard Mitigation Plan was completed in 2026. The 2026 Puerto Rico State Natural Hazard Mitigation Plan establishes long-term strategies to address natural hazards that have the potential to disrupt daily activities, damage property, and threaten human life. These hazards may become disasters that affect not only individuals, but also entire communities, with broad impacts on public health, infrastructure, economic stability, and natural ecosystems (NMEAD, 2026).

This plan provides a comprehensive framework for identifying risks and implementing actions aimed at reducing vulnerability to these hazards. Through its emphasis on mitigation, the plan seeks to increase community resilience, protect critical infrastructure and systems, and promote sustainable development throughout Puerto Rico (NMEAD, 2026).

Figure 5. Puerto Rico SHMP Cover



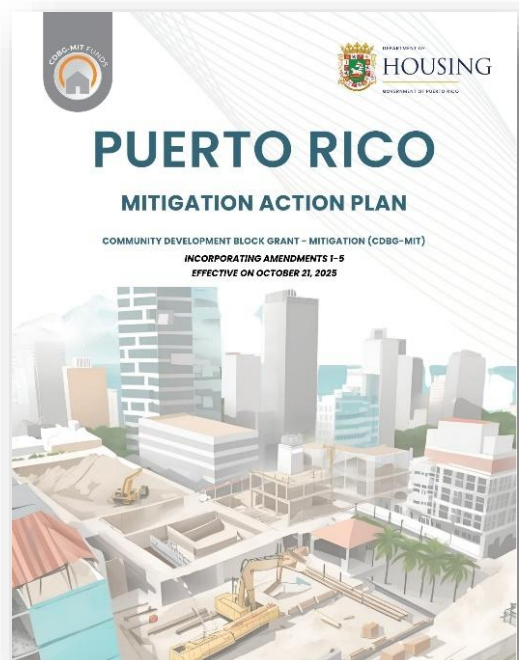
The Municipality of Aguada reviewed the 2026 Puerto Rico State Hazard Mitigation Plan during the preparation of this LHMP update. The relevant risk profiles, state capabilities, mitigation goals, and state actions were considered during the risk assessment, capability assessment, and development of the municipal mitigation strategy.

Puerto Rico Mitigation Action Plan, CDBG-DR MIT (2021, 2025)

Originally approved by the U.S. Department of Housing and Urban Development (HUD) in 2021 and subsequently amended in August 2025, the Puerto Rico Mitigation Action Plan for the Community Development Block Grant–Mitigation (CDBG-MIT) Program is a strategic planning document prepared by the Puerto Rico Department of Housing (PRDOH). The plan establishes the framework for the administration and management of federal mitigation funds allocated by HUD under the CDBG-MIT program.

Figure 6. Puerto Rico Mitigation Action Plan Cover

Its primary objective is to reduce risks and vulnerabilities to future disasters by enhancing the resilience of infrastructure, communities, and critical systems. Although these funds were appropriated by Congress to Puerto Rico following Hurricanes Irma and María in 2017, CDBG-MIT funding differs from CDBG-Disaster Recovery (CDBG-DR) in that it is specifically focused on preventing and mitigating future impacts. Accordingly, CDBG-MIT resources are directed toward sustainable, high-impact mitigation projects and are not required to be directly linked to disaster recovery activities associated with the 2017 hurricanes (PRDOH, 2025). Overall, this plan is designed to reduce exposure to hazards, safeguard lives and property, and enhance emergency response capabilities through targeted investments in infrastructure, housing, and land-use planning (PRDOH, 2025).



1.1.3 Municipal Policies

Aguada Local Hazard Mitigation Plan (2020)

Adopted on November 2020, the Aguada Local Hazard Mitigation Plan (LHMP) complies with the federal Disaster Mitigation Act of 2000 and establishes a comprehensive framework to reduce risks to life and property from natural hazards.

The planning process included active participation from municipal officials, agencies, and the public. A Mitigation Planning Committee led outreach efforts through public meetings, public notices, and the publication of draft documents for community review, ensuring stakeholder input throughout the plan's development.

The assessment identified flooding as the most significant hazard affecting Aguada, while earthquakes, drought, high winds associated with tropical cyclones, and tsunamis were also determined to pose substantial risks. The updated plan emphasizes protecting lives and property, strengthening critical infrastructure, enhancing emergency management capabilities, and increasing the municipality's overall resilience to future disasters.

Figure 7. Aguada All Hazard Mitigation Plan Cover



Mitigation strategies are organized into key categories, including prevention, property protection, natural resource protection, structural projects, emergency services, and public education. The largest number of actions fall under Property Protection, with particular emphasis on addressing flooding and landslides.

Some of the mitigation strategies proposed by the Aguada LHMP (2020) are:

- **Flooding:** Implement flood control projects for communities adjacent to or near the Culebrinas River and prioritize measures that reduce repetitive flood losses to residents, infrastructure, and critical facilities.
- **Tropical Cyclones/Extreme Winds:** Strengthen critical facilities, public infrastructure, and essential municipal services to reduce damage and operational disruptions during tropical storms and hurricanes.

- **Earthquakes:** Promote structural and infrastructure improvements that reduce seismic risk to critical facilities and support continuity of municipal operations following earthquake events.
- **Drought:** Implement actions that improve the municipality's ability to prepare for, respond to, and withstand prolonged water shortages and drought conditions.
- **Tsunamis:** Enhance preparedness, emergency response capabilities, and public awareness efforts to reduce risks to coastal communities and municipal assets.
- **Landslides:** Identify and address areas vulnerable to slope failure in order to protect public safety, infrastructure, and property.
- **Sea Level Rise, Coastal Erosion, and Storm Surge:** Support long-term mitigation and planning initiatives that reduce the vulnerability of coastal areas, infrastructure, and community assets to changing coastal conditions.
- **Wildfire:** Maintain prevention, preparedness, and emergency management measures that reduce the potential impacts of wildfire events on municipal facilities and communities.
- **Infrastructure Resilience:** Retrofit and strengthen the bridge located in Lagunas Ward and pursue improvements to vulnerable infrastructure that support community resilience to future hazard events.

Aguada Municipal Recovery Plan

As part of the CDBG-DR funds assigned by Congress to Puerto Rico in the aftermath of hurricanes Irma and María, municipalities were able to develop a recovery plan to guide recovery efforts and resiliency in the event of future stressors. In essence the Municipal Recovery Plans:

- Identify local post-disaster needs created or worsened by Irma and María
- Establish short-, medium-, and long-term recovery priorities
- Integrate resilience and hazard mitigation strategies
- Serve as a policy and project roadmap for future funding decisions

Figure 8. Aguada Recovery Plan



Each Municipal Recovery Plan has a list of recovery and resiliency projects that might be considered as new mitigation strategies for the LHMP.

1.2 Scope and Previous Versions

1.2.1 Primary Objectives

The primary objectives of the LHMP are to:

- Identify and assess natural hazards that pose a risk to the municipality.
- Develop strategies and actions to reduce or eliminate long-term risks to life, property, and essential services.
- Promote interagency coordination and community engagement in disaster preparedness and mitigation efforts.

1.2.2 Previous FEMA Comments

The following recommendations and requirements were made by FEMA upon approving the previous 2020 LHMP for Aguada.

Element A.2

- *Recommendation – “It is recommended that for future revisions, meetings should be held and considered that are particularly aimed at addressing the specific problems of the Aguada municipality. Meetings such as working groups that bring together many representatives and that could have a more comprehensive purpose, may not work as effectively as desired in the best development of the municipal Plan. Citizen participation in the development of the 2020 Natural Hazard Mitigation Plan for the Municipality of Aguada should be more directed through the following methods: (1) through public outreach and informational workshops and (2) through online comments, as proposed in the Plan.”*
- Municipality’s response – The 2026 LHMP update included targeted stakeholder outreach and public participation activities. The municipality coordinated with neighboring municipalities, government agencies, community organizations, and other stakeholders through formal correspondence and public

involvement activities. Public participation included community meetings, public notices, online outreach, and opportunities for public review and comment throughout the planning process.

Element A.3

- Recommendation – *“The surveys carried out among the citizens are of great help in the generation and collection of data that contribute to the development of Hazard Mitigation Plans, among others. The larger the sample, the more relevant the results will be to the universe in question. Generate a report from the analysis of the data collected through the survey will result in a very extended and comprehensive LHM Plan.”*
- Municipality’s response – For this LHMP, the Municipality did not conduct a formal public survey. Instead, community input was obtained through public participation activities, including community meetings, and the public comment process. These activities provided an opportunity for residents and stakeholders to share their experiences, concerns, and recommendations regarding natural hazards affecting the municipality. The information collected through these engagement efforts was considered during the development of hazard assessment, risk analysis, and mitigation strategy. Therefore, the Municipality determined that sufficient public input was obtained through these participatory processes and did not implement a separate survey instrument for this planning effort.

Element B.3

- Recommendation – *“Financial losses are foreseen for flood and earthquake risks. However, losses from other hazards are presented in terms of area, population affected or more generally. Providing additional estimates of dollar losses or economic impacts on all hazards that threaten the municipality will prepare the municipality for the possibility of future natural disasters affecting it. Also, may advance the process of applying for and receiving financial assistance through the various programs available. When using ‘best data available’, refer to a most recent version of the information enquired.*
- Municipality’s response – The hazard risk assessment was updated using the best available data sources, including FEMA National Risk Index datasets, HAZUS modeling, and other federal and Commonwealth information sources. Where available, estimated economic losses and annualized losses were incorporated

into the hazard analyses to support mitigation planning and future funding opportunities.

Element B.4

- Recommendation – *“The municipality will need to update the RL and SRL, NFIP information as soon as is available, as stated in the p. 75 of the plan.”*
- Municipality’s response – NFIP participation information, including policies in force, Repetitive Loss (RL) properties, Severe Repetitive Loss (SRL) properties, and associated claims information, was updated using the most current information available at the time of the 2026 LHMP update.

Element C.3

- Recommendation – *“The plan states that the public’s input was one of the factors for identifying the mitigation objectives. However, there is no detailed information on the text or appendices of what kind of feedback was received from the public during the plan’s development. Consider including additional documentation of the public’s input.”*
- Municipality’s Response – Public input received through community meetings, outreach activities, and stakeholder engagement efforts was documented and incorporated into the development of mitigation goals, objectives, and mitigation strategies. Additional supporting documentation is included within the plan appendices.

Element C.5

- Recommendation – *“Describe the criteria used to prioritize implementation of actions, at a minimum the plan must summarize the economic considerations. Explain whether the benefits of a mitigation action are expected to outweigh the costs. The plan must describe how economic considerations are part of the community’s prioritization (ranking) of mitigation actions for implementation. At a minimum, explain how projected benefits from the mitigation actions were compared against likely project costs.”*
- Municipality’s Response – The updated mitigation strategy incorporates the STAPLEE methodology and includes implementation priorities, responsible entities, potential funding sources, implementation timeframes, and economic considerations for evaluating and prioritizing mitigation actions.

- *Recommendation – “Expand the description of economic considerations (e.g. benefits of the mitigation action vs. cost of action) by estimating past costs of hazard impacts the mitigation action might reduce. Including this information will benefit the municipality by allowing future officials and residents to understand why certain actions were selected. The costs presented in the previous Plan (2013) could be tempered to current costs for the continuous action strategies. Documenting this information may also be useful to include for future reference when updating the plan and its actions within the 5-year cycle.”*
- **Municipality’s Response** – Additional economic considerations were incorporated into the mitigation strategy through the evaluation of implementation costs, potential funding sources, project benefits, expected loss reduction, and long-term community resilience benefits associated with proposed mitigation measures.

Element D.1

- *Recommendation – “The municipality will benefit greatly from an analysis such as the one presented in this Plan, for those prone areas, between years 2015 and 2019. However, it should include the previous two years covering the term since the last approved Plan between years 2013 to 2015. If no changes in development impacted the jurisdiction’s overall vulnerability during this time period, it must be stated.”*
- **Municipality’s Response** – The 2026 LHMP includes an updated evaluation of recent development trends and construction activity occurring since the previous plan update. Development patterns, issued permits, recent growth areas, and future conditions were incorporated into the vulnerability assessment and hazard analyses.

Element E.1

- *Requirement – “The jurisdiction approved the Executive Order Number 15, Serie 2020-2021 on N “The jurisdiction approved the Executive Order Num. seven (7) Series 2020-2021 on November 02, 2020. That Ordinance adopts the Local Hazard Mitigation Plan of the Municipality of Aguada. The ordinance should be incorporated in the final Plan and submitted to FEMA.”*
- **Municipality’s response** – Adoption documentation is provided in Appendix A and will be submitted to FEMA as part of the final approved LHMP.

1.3 LHMP Organization

The following table shows the layout for the 2026 of Aguada LHMP. To help LHMP reviewers and the public understand compliance, the table includes a column specifying which FEMA-required element (FEMA, 2025) is addressed by each section.

Table 1. LHMP Organization

Chapter #	Title	Description	Review Tool Elements met
N/A	Executive Summary	This section summarizes the most important findings from the planning process and explains how they are addressed in the LHMP.	Local Element
Chapter 1	Introduction and Background	This chapter discusses the planning background for Aguada. It explains the organization of the LHMP, the most significant changes in the 2026 version compared to the 2020 version, and the public policies relevant to the update of the LHMP.	E2-a, A1-a, A1-b, A4-a, A2-a, A3-a
Chapter 2	Planning Process	This chapter describes the planning process used to develop the 2026 Aguada LHMP, including regulatory requirements, plan development activities, planning committee participation, public outreach efforts, citizen participation, and stakeholder involvement.	E1-a
Chapter 3	Municipal Profile	The municipal profile describes the municipality's relevant characteristics, including physical features, infrastructure, and demographic and socioeconomic traits.	B-1a, B-1b, B1-c, B1-d, B-e, B2-a, B2-b, E1-a
Chapter 4	Hazard Profiles and Risk Analysis	This section is the most extensive in the plan. It covers the hazards identified for Aguada and examines the risks associated with each one.	B-1a, B-1b, B1-c, B1-d, B-e, B2-a, B2-b, E1-a
Chapter 5	Municipalities Capacities	This chapter elaborates on the municipality's capabilities to implement the mitigation strategies that will be proposed in Chapter 6.	C1-a, C-1b

Chapter #	Title	Description	Review Tool Elements met
Chapter 6	Mitigation Action Plan	This chapter establishes the mitigation goals of the Plan and the actions the municipality will take to reduce the risks associated with the identified natural events. It also serves to update the status of the mitigation actions included in the 2020 Plan.	C3-a, C4-a, C4-b, C5-a, C5-b, E2-b
Chapter 7	Plan Maintenance	This chapter addresses the process for evaluating the effectiveness of the plan. It also explains the procedure for making modifications or updates to the plan.	D1-a, D2-a, D2-b, D2-c, E2-c
Chapter 8	Adoption and Approval	This section includes information on the adoption of the plan by the municipality, FEMA's approval, and the expiration date of the 2026 Local Hazard Mitigation Plan.	F1-a, F1-b
N/A	References	This section presents the sources used in updating the plan.	A4-a
N/A	Appendixes	This section includes all appendices and supplementary information related to the planning process of the Plan.	

1.4 Changes to the Aguada LHMP (E2-a)

The following table shows the most significant changes that the 2026 version has from the 2020 version.

Table 2. Changes to the Aguada LHMP

Element	Justification
Plan Language	Following Presidential Executive Order #14224, the 2026 version of Aguada LHMP has been originally prepared in English for submission and consideration of FEMA. An official translation of the final draft for public discussion and the final approved LHMP to Spanish will be prepared for the benefit of the population that are not English proficient.
Plan organization	The organization and chapters of the document have been modified to follow the template used in local mitigation plans prepared by the Puerto Rico Planning Board. However, this template has been adapted in the current plan to comply with current federal public

Element	Justification
	policy.
Discussion of FEMA Lifelines	As per the Local Hazard Mitigation Policy, FEMA Lifelines are discussed as well as the strategies to mitigate hazard impacts on them.
Elimination of non-applicable public policy	For clarity and better readability, references to redundant public policy have been removed.
Change to the name of extreme winds	The hazard identified in the 2020 Plan as “Extreme wind” has been changed to “Tropical Cyclones/Extreme Winds” to the current HAZUS capability to model tropical cyclones for Puerto Rico.
Update of census data	The municipality and PRPB have chosen to use the most recent version of the American Community Survey for evaluating demographic data. In this case it has chosen to evaluate the data sets from the 2024 five-year American community survey.
Action Plan	A new strategy ID has been added to help municipalities and commonwealth agencies keep track of them.
All the LHMP	Attention has been given to ensure that the content of the Plan does not reveal any personally identifiable information (PII).

2. Planning Process

2.1 Planning Process Regulations

This LHMP was updated following the applicable public policies and procedures mentioned in Chapter 1.

This LHMP seeks to aid municipality in the task of preventing loss of life and property by the effects of natural hazards. Chapter 1 serves as a general introduction, Chapter 2 discusses the planning process followed, as well as stakeholder and public participation involvement. The LHMP identifies a general profile of the municipality using information provided by the US Census, such as population distribution, employment, housing stock, etc. (see Chapter 3 for more information). After describing the Municipality's general profile, the Plan goes on to evaluate all identifiable natural hazards that can affect the municipality and its population, including the effects on lifelines, properties, population exposure, natural resources, etc. (see Chapter 4 for more information).

Chapter 5 defines the capabilities that the municipality has for implementing the LHMP. While Chapter 6, establishes the mitigation actions that the municipality will execute for the next five years. Chapter 7 discusses the provisions for LHMP Maintenance and Chapter 8 discusses the adoption and approval of the LHMP. The various appendixes hold supporting information.

2.2 History of the LHMP

This document represents the second revision of the LHMP for the Municipality of Aguada. The original plan received FEMA approval in 2013, followed by the first update approved in November 2020. This 2026 update reflects evolving conditions and circumstances that have influenced the municipality over the past five years and incorporates newly enacted laws, programs, and regulatory requirements. Through this update, Aguada aims to preserve its eligibility for federal mitigation funding prior to future catastrophic events and to present a strengthened plan aligned with current standards and best practices.

2.3 Plan Preparation, Revision Schedule and Methodology (A1-a)

The Municipality and its consultants followed the natural hazard mitigation planning process as established by FEMA in the Local Hazard Mitigation Planning Guide and the Local Hazard Mitigation Planning Handbook, as well as the recommendations provided by the mitigation planning staff of Central Office for Recovery Reconstruction and Resiliency (COR3) which has a dual role as State Hazard Mitigation Officer (SHMO). The Local Mitigation Plan Review Tool provides a summary of FEMA's current minimum standards to comply with mitigation planning requirements and identifies where each requirement is addressed within this Plan.

Following federal law, LHMPs must be updated every five (5) years for the municipality to remain eligible for federal mitigation funding. To prepare the 2026 LHMP, AtkinsRéalis Caribe, LLP, under contract with the Puerto Rico Planning Board, provided professional mitigation planning services to support the development of the Municipality's plan update.

The planning process for the 2026 update of the Aguada Local Hazard Mitigation Plan (LHMP) officially began with the execution of a Letter of Agreement between the Municipality of Aguada and the Puerto Rico Planning Board (PRPB), which was signed on December 16, 2025. A copy of the signed agreement is included in Appendix B. Subsequently, a kickoff meeting was held on February 6, 2026, bringing together representatives from the Municipality and the PRPB to discuss the planning process, project objectives, and coordination efforts. Later a consulting firm, AtkinsRéalis Caribe LLP, was retained by the PRPB to support the mitigation planning efforts.

The revision phase reached completion upon the official delivery of the final draft to the State Hazard Mitigation Officer (SHMO), within the Central Office for Recovery, Reconstruction and Resiliency (COR3), on [Click or tap to enter a date.](#) The revision process lasted ___ days.

2.4 Planning Committee (A1-a, A1-b)

To support the revision of the Aguada LHMP, a Planning Committee was established, comprised of representatives from several municipal dependencies who were designated to guide the process. The members of the Committee are:

Table 3. LHMP Planning Committee

Name	Position
Wesley Vega López	Director of Planning Office
Marisol Rosa Acevedo	Municipal Administrator
Jairo Jiménez	Administrative Assistant for Emergency Management Office
Jimmy L. Hernández	Commissioner of Municipal Police
Javier Feliciano	Director of Public Works
Héctor Cajigas	Director of Environmental Control
Damaris Feliciano	Director of Federal Programs
Carlos A. Rodríguez	Community Representant
Aníbal Nieves	Community Representant

The function of this Planning Committee is to support and coordinate the update, implementation, and monitoring of the Municipality of Aguada's Hazard Mitigation Plan, while providing guidance on risk reduction strategies, ensuring compliance with mitigation requirements, and promoting community participation to strengthen municipal resilience.

The designation letter for the Planning Committee is included in Appendix B. This appendix also compiles the meeting minutes, documentation of the materials discussed throughout the process, and accompanying photographic evidence.

2.5 Citizen Participation (A3-a)

2.5.1 Community Outreach and Public Participation Strategies

The public participation approach selected for this LHMP revision incorporated the following activities:

- **Distribution of notification letters** to agencies, neighboring municipalities, community leaders, nonprofit organizations, neighborhood associations, business or industrial groups, and other interested stakeholders, informing them that the LHMP revision process had commenced and inviting their input. Documentation of these communications is included in Appendix C.
- **Publication of notices on the Municipality's website and official social media platforms** to inform the public that the LHMP revision was underway. These

postings also provided an email address to gather information regarding the community's experiences with natural hazards. Evidence of these public notices is also maintained on Appendix C.

- **Convening an initial community meeting** to introduce the LHMP revision process. This step involved:
 - Issuing a public announcement in a newspaper, on the Municipality's website, and across official social media channels at least 15 days before the meeting.
- **Holding a second community meeting** to discuss the hazard assessment and analysis with the public. This stage included:
 - Publishing a newspaper announcement and posting notices on the Municipality's website and official social media outlets at least 15 days before the meeting.
 - Confirming in the announcement that the draft plan was available for review in printed and online versions.
 - Providing an additional 15-day comment window for the community to offer feedback, either by email or by visiting the designated address.

2.5.2 Community Outreach and Public Participation Results

First Public Meeting Results

A public meeting notification announcing the initiation of the LHMP update process was published on 2/23/2026 via "El Vocero de Puerto Rico" newspaper. The notification informed the public that the meeting would be held on 3/10/2026 in the "Biblioteca Municipal Edith Nilda López Soto" at 6:00 pm.

During the meeting, participants identified concerns related to recurring flooding, drainage deficiencies, stormwater management, channel maintenance, coastal erosion, shoreline protection, natural resource conservation, and the vulnerability of coastal communities to tsunamis, tropical cyclone, and tornado hazards. Residents also expressed concerns regarding the impacts of existing and proposed flood control projects, deterioration of natural drainage systems, blocked waterways, flooding associated with rivers, streams, and coastal areas, and the need to preserve environmentally sensitive areas and natural protective features. Additional comments highlighted the importance of improving emergency preparedness, evaluating vertical evacuation options, strengthening protection of rivers, streams, wetlands, and coastal resources, addressing vulnerabilities affecting older adults and coastal

communities, and considering greater use of green infrastructure and nature-based solutions as part of future mitigation efforts.

In response, the Municipality incorporated these concerns into the hazard identification, risk assessment, and mitigation strategy development process. Community comments were evaluated as part of the assessment of flooding, coastal hazards, tsunami risk, tornado and extreme wind events, natural resource protection, and future development vulnerabilities. Input received during the meeting also supported the consideration of mitigation actions related to flood risk reduction, stormwater management, emergency preparedness, public education, shoreline and environmental resource protection, nature-based solutions, evacuation planning, and infrastructure resilience. The planning process further considered comments regarding vulnerable populations, community facilities, and the long-term protection of coastal and environmentally sensitive areas.

Appendix C includes the notes documented by the planning consulting firm during the activity, along with supporting evidence. All documentation complies with PII protection requirements.

Second Public Meeting Results

A public meeting notification to present the draft of LHMP was published on Click or tap to enter a date. via _____. The notification informed the public that the meeting would take place on Click or tap to enter a date. in _____ at _____. It also stated that a printed copy of the draft LHMP would be available at

_____ during regular work hours. Additionally, the public had the option of accessing the draft LHMP through the webpage _____. Copies of the public notification are included in Appendix C.

During this meeting, participants expressed the following concerns:

The Municipality took the following measures to address these concerns: _____. Appendix C includes the notes documented by the planning consulting firm during the activity, along with supporting evidence. All documentation complies with PII protection requirements.

2.6 Stakeholder Involvement (A2-a)

The Municipality carried out outreach efforts to external stakeholders, including government agencies and neighboring municipalities, through formal correspondence addressed to agency heads and mayors. Copies of these invitation letters are provided in Appendix D. Stakeholders were encouraged to submit input either via email or by participating in the public involvement process.

Input from internal stakeholders was obtained through the Planning Committee. Appendix D also includes any written responses or correspondence received from stakeholders during this outreach process.

2.6.1.1 Hazard Analysis Data Sources

The following table presents the datasets utilized for the evaluation of each hazard. Table 4 identifies the hazards considered in this LHMP and the corresponding data sources used to support their assessment.

Table 4. Hazard and Risk Assessment of Data Sources

Hazard	Data Sources	Comments
Earthquake	USGS, FEMA	HAZUS 6.1 used
Landslides	USGS	
Tsunami	NOAA, FEMA	
Flooding	FEMA	HAZUS 6.1 used
Tropical Cyclone/Extreme Winds	FEMA	HAZUS 6.1 used
Extreme Heat	NOAA	
Drought	NDIM	
Wildfire	Puerto Rico Fire Bureau	
Long – Term Coastal Dynamics	NOAA, UPR- COREPI	
Pandemic/Epidemic	PR Department of Health	

2.7 FEMA Lifelines

The *Local Mitigation Planning Handbook* and the *Local Hazard Mitigation Planning Policy Guide* highlight the importance of integrating critical lifelines into the hazard mitigation planning process. FEMA defines lifelines as essential services that sustain public safety, economic stability, and the continuity of government and daily life before, during, and after an emergency or disaster. These lifelines serve as a

framework for prioritizing resources and actions that are essential to reducing loss of life and property and supporting efficient and rapid recovery following hazard events (FEMA, 2023).

FEMA identifies eight (8) primary lifelines:

- **Safety and Security:** Includes law enforcement, fire services, search and rescue operations, government services, and community safety functions.
- **Food, Hydration, and Shelter:** Encompasses food systems, water access, emergency shelter, and agricultural resources.
- **Health and Medical:** Includes medical care, public health services, patient movement, medical supply chains, and healthcare facility management.
- **Energy:** Covers the electrical power grid and fuel supply systems.
- **Communications:** Includes communications infrastructure, responder communications, alert and warning systems, financial services, 911 operations, and emergency dispatch.
- **Transportation:** Encompasses highways, motor vehicle systems, mass transit, railways, aviation, and maritime transportation.
- **Hazardous Materials:** Includes facilities and systems associated with hazardous materials, pollutants, and contaminants.
- **Water Systems:** Includes potable water infrastructure and wastewater collection and treatment systems.

Each of these lifelines is supported by sub-lifelines that allow jurisdictions to more precisely identify vulnerabilities and prioritize recovery actions. Together, they enable emergency managers and decision-makers to rapidly assess conditions, focus response operations on the most critical needs, and coordinate actions that directly affect human life and community stability.

By monitoring the status and functionality of lifelines, jurisdictions can respond more effectively during emergencies, minimize cascading impacts, and accelerate more resilient recovery. A detailed discussion of lifelines and their relevance to the Municipality of Aguada is provided in Section 3.5.

3. Municipal Profile

The Municipality of Aguada is on the western coast of Puerto Rico. It borders the following municipalities: to the north, Aguadilla; to the south, Rincón and Añasco; to the east, Moca; and to the west, Rincón.

Aguada is subdivided into eighteen (18) wards (barrios): Aguada Pueblo, Asomante, Atalaya, Carrizal, Cerro Gordo, Cruces, Espinar, Guanábanas, Guayabo, Guaniquilla, Jagüey, Lagunas, Mal Paso, Marías, Mamey, Naranjo, Grande River from Añasco and Piedras Blancas.

Map 1 shows the geographical area of Municipality of Aguada and its adjacent municipalities. Map 2 shows the distribution of its wards (“barrios”).

3.1 Data Sources for Municipal Profiles

The Aguada LHMP has been updated using the most current demographic and socioeconomic data available. Municipal profiles and risk assessments rely primarily on the 2020–2024 Five-Year American Community Survey (ACS). When specific information is not available through the ACS, alternative data sources are identified and cited in the corresponding footnotes.

In addition, the plan reflects the most up-to-date knowledge on hazards and mitigation practices. References to relevant plans, studies, and technical reports are provided in page-level footnotes and consolidated in the References section.

GIS layers included in Chapter 3 were mostly provided by the PRPB’s GIS Office.

3.2 Brief Historical Background

The Municipality of Aguada, also known as “The City of Discovery,” is one of the 78 municipalities of Puerto Rico. It is located in the western coastal valley region, bordering the Atlantic Ocean—east of Rincón, South of Aguadilla, west of Moca, and north of Añasco. According to the Metropolitan Statistical Area (MSA) used by Census, the municipality of Aguada forms part of the Aguadilla–Isabela–San Sebastián Metropolitan Statistical Area.

Aguada is considered the second settlement founded on the Island, after Caparra. Its origins date back to 1510, when Don Cristóbal de Sotomayor, lieutenant of Juan Ponce de León, established the first settlement under the name Villa de Sotomayor. Later, in 1692, King Charles II of Spain elevated this small settlement in status, along with the towns of Ponce, Arecibo, Coamo, and Loíza. Historically, Aguada was known as Villa de San Francisco de Asís de la Aguada. The name Aguada refers to the place where Spanish ships stopped to replenish fresh water, while San Francisco de Asís references the monastery that King Ferdinand ordered to be built in the area, highlighting the town’s religious significance during the colonial period.

3.3 Geography

The Municipality of Aguada covers an area of 19,911.55 *cuerdas*¹, equivalent to 30.21 square miles. Aguada is located within Puerto Rico’s Western Coastal Plains, a region characterized by fertile alluvial soils and a landscape that transitions from coastal lowlands to gently rolling interior hills. Although much of the municipality features relatively flat terrain, the southern area becomes more elevated, forming part of the San Francisco ridge system, also known as La Cadena, which extends across the southern portion of the municipality.

Notable elevations within Aguada include:

- Pico Atalaya, located on the boundary between Aguada and Rincón, with an elevation of approximately 362 meters (1,187 feet).
- Cerro Gordo, situated in the ward of the same name, with an elevation of about 260 meters (853 feet).

¹ In Puerto Rico, a *cuerda* is a traditional unit of land measurement. It’s similar to an acre but slightly smaller. 1 cuerda = about 3,930 square meters (m²). In acres, that’s roughly 0.97 acres. In hectares, it’s about 0.393 hectares.

- Smaller hills—Casualidad, Cayures, San José, Vadi, and Vieques hill—which do not exceed 76 meters (249 feet) above sea level.

These geographic features create a varied topography in which coastal plains dominate the northern half of the municipality, while more rugged terrain is concentrated toward the south.

Aguada is also traversed by several rivers of hydrologic importance, including the Cañas River, Culebrinas River, and Culebra River, which influence the municipality's drainage patterns and contribute to local flood susceptibility (Municipality of Aguada, 2024)².

Map 1 illustrates the geographic location of Aguada within the western region of Puerto Rico. The municipality occupies a coastal setting along the Atlantic Ocean and forms part of the island's western coastal plain. The map provides regional context by showing Aguada's location relative to neighboring municipalities and highlights its position between the coastal lowlands to the north and the more mountainous interior regions to the south.

Map 2 illustrates the municipal ward boundaries within Aguada. The municipality is subdivided into eighteen barrios: Atalaya, Asomante, Barrio Pueblo, Carrizal, Cerro Gordo, Cruces, Espinar, Guanábano, Guaniquilla, Guayabo, Jaguey, Lagunas, Mal Paso, Marías, Naranjo, Piedras Blancas, Grande River from Añasco, and Mamey. The map shows the spatial distribution and extent of these administrative units, which vary in size and geographic characteristics. Coastal barrios are generally located along the northern portion of the municipality, while the larger interior barrios occupy the more elevated southern and southeastern areas.

² Many of the resources used for the preparation of LHMP update are in Spanish. For uniformity the bibliographical entries and citations of the sources will be translated to English.

Map 1. Geographical Area

GEOGRAPHIC AREA



Source: Puerto Rico Planning Board

SPCS PR & VI NAD83



Map 2. Wards

WARDS BOUNDARIES



3.3.1 Physiography

Aguada exhibits a varied topographic structure shaped by the western coastal valley region lowlands and adjoining hilly to mountainous terrain. Regional descriptions indicate elevations that rise toward the foothills between Aguada and Maricao, where the broader region includes prominent landforms such as elevations associated with the Cordillera Central's southwestern outliers. (EnciclopediaPR, 2010)

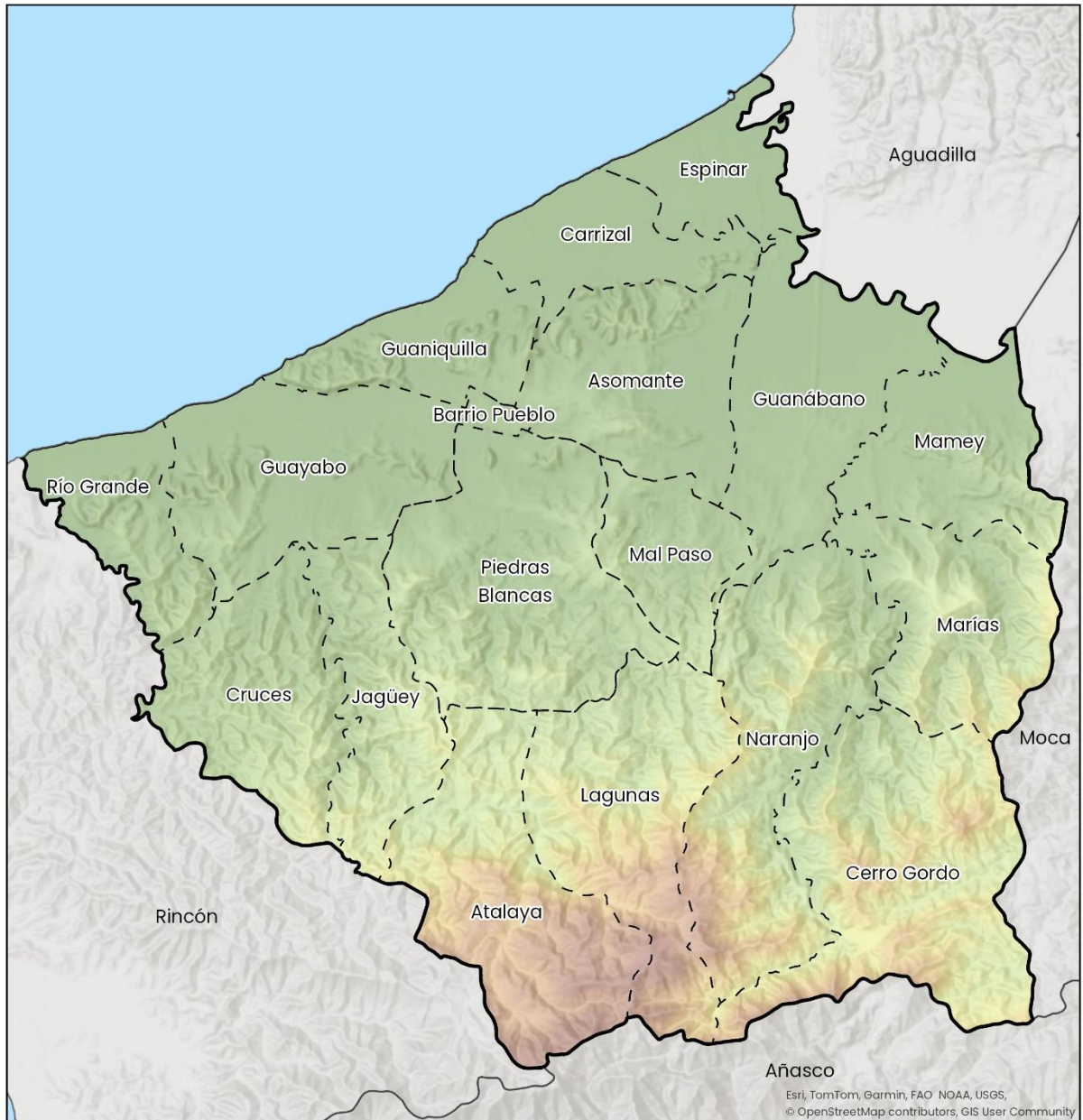
The Plan Territorial – Memorial (2012) emphasizes that this coastal valley-to-upland transition historically influenced settlement choices, agricultural patterns, and regional circulation routes. These gradients produce areas of high slope, variable soil stability, and complex runoff behavior, which today are directly relevant to hazard mitigation, particularly for landslide susceptibility, limited access in hillside barrios, and increased runoff velocities entering valley neighborhoods.

Map 3 illustrates the physiographic characteristics of Aguada and the distribution of elevation across the municipality. The map shows a clear transition from the low-lying coastal and interior plains in the northern and central portions of Aguada to progressively higher and more rugged terrain toward the south. The lowest elevations are concentrated along the Atlantic coastline and throughout much of the central portion of the municipality, including areas of Espinar, Carrizal, Guaniquilla, Asomante, Guanábano, Guayabo, and Barrio Pueblo.

Elevation gradually increases southward, where more pronounced hills and mountainous terrain are visible in the barrios of Atalaya, Lagunas, Naranjo, Cerro Gordo, Marías, Cruces, and Jagüey. According to the map, municipal elevations range from near sea level to over 360 meters above mean sea level, with the highest terrain concentrated along the southern municipal boundary adjacent to Añasco, Moca, and the upland interior region.

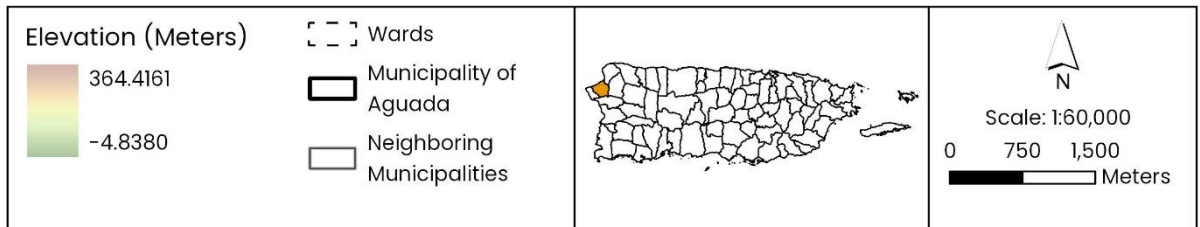
This north-to-south elevation gradient influences drainage patterns, land use, transportation accessibility, and hazard exposure throughout Aguada. The flatter coastal and valley areas have historically supported greater development and connectivity, while the steeper southern sectors present additional challenges related to slope stability and access. From a hazard mitigation perspective, the higher-elevation areas may be more susceptible to landslides and erosion during heavy rainfall events, while runoff generated in these upland areas contributes to the drainage systems that flow toward the municipality's lower valleys and coastal plain.

PHYSIOGRAPHY



Source: Puerto Rico Planning Board and United States Geological Survey

SPCS PR & VI NAD83



3.3.2 Geology

This territory includes portions of the Aguada Limestone and the Cibao Formation. The remaining municipal area corresponds to the Paleocene and/or Eocene periods and is composed primarily of limonite, sandstone, conglomerate, lava, and tuff. The Municipality of Aguada has an average width of approximately 10 miles from the coastline to the point where it meets the volcanic rock slopes of the Central Mountain Range. (Municipality of Aguada, 2024)

Aguada forms part of Puerto Rico's western geological province, characterized by a combination of sedimentary and volcanic formations that reflect the island's complex tectonic evolution. The sedimentary units present in the municipality, including the Aguada Limestone and the Cibao Formation, are associated with the island's early marine depositional environments, while the presence of conglomerates, lava, tuff, and other volcanic materials toward the south indicates the influence of volcanic and plutonic activity linked to the uplift of the Central Mountain Range. These contrasting lithologies contribute to spatial variations in soil composition, groundwater storage capacity, and terrain stability, which are relevant considerations for hazard mitigation planning, particularly regarding landslides, erosion, and subsurface infiltration behavior.

3.3.3 Hydrography

The hydrographic system is composed of surface water bodies (such as rivers and streams) and groundwater bodies. The main water bodies are the Culebrinas River and the Grande River from Añasco, both of which are part of the Culebrinas River watershed. The Culebrinas River contains one of the three largest alluvial valleys in western Puerto Rico. The river originates in Lares, flows through San Sebastián and Moca, and continues northeast into Aguada, where it empties into the Atlantic Ocean. Other important water bodies in the municipality, which are also part of the Culebrinas River watershed, include the Ingenio, Culebras, and Guayabo rivers. (Municipality of Aguada, 2024)

Along the coast of Aguada, the headland known as *Boquerón*, located in the Carrizal ward, stands out. Additionally, the municipality contains manganese deposits and small quantities of copper. According to the United States Geological Survey (USGS) *Atlas of Groundwater Resources of Puerto Rico and the U.S. Virgin Islands* (1996), the central region of Puerto Rico is classified as a volcanoclastic, igneous, and sedimentary

rock aquifer. The atlas indicates that volcanoclastic, igneous, and sedimentary rock aquifers are considered minor aquifers. These aquifers generally yield less than 10 gallons per minute to wells, particularly in areas intruded by plutonic rocks. The municipal territory also contains sections of the alluvial aquifer and of the northern coastal karst aquifer. (Municipality of Aguada, 2024)

The hydrologic behavior of the municipality is further shaped by the presence of alluvial deposits and low-lying plains that facilitate natural groundwater recharge and influence surface runoff patterns. Seasonal rainfall contributes to fluctuations in streamflow, particularly across intermittent creeks that activate during heavy precipitation events and channel drainage toward the Culebrinas River system. These hydrologic dynamics play an important role in soil moisture retention and aquifer replenishment throughout Aguada.

Map 4 illustrates the hydrographic system of the Municipality of Aguada, highlighting the extensive network of rivers, streams, and tributaries that drain the municipality toward the Atlantic Ocean. The principal watercourses include the Culebrinas River, Guayabo River, and Grande River from Añasco, as well as coastal drainage features such as Caño Madre Vieja and Caño de Santi Ponce. Together, these waterways form a dense drainage system that influences local hydrology, flood patterns, and watershed management throughout the municipality.

Map 5 presents the major watershed basins associated with Aguada. Most of the municipality is located within the Culebrinas River Watershed, while smaller portions of the southern municipality drain toward the Grande River from Añasco watershed. These watershed boundaries illustrate how surface water generated within Aguada contributes to larger regional drainage systems extending beyond municipal limits.

Map 6 illustrates the sub-watershed basins associated with Aguada, including the Guayabo River, Culebrinas River at Mouth, El Gallinero Creek, Las Marías Creek, Caño de Santi Ponce- Grande River from Añasco, Caño La Puente, Humata River, and the Coastal Watersheds East and West of Culebrinas River Mouth. These sub-watersheds define local drainage patterns and help identify how runoff is conveyed throughout the municipality, providing useful information for flood risk assessment, stormwater management, and watershed protection efforts.

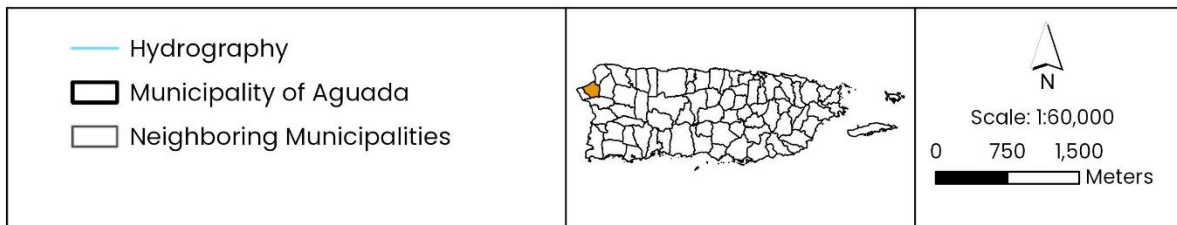
Map 4. Hydrographic

HYDROGRAPHY



Source: Puerto Rico Planning Board and United States Geological Survey

SPCS PR & VI NAD83



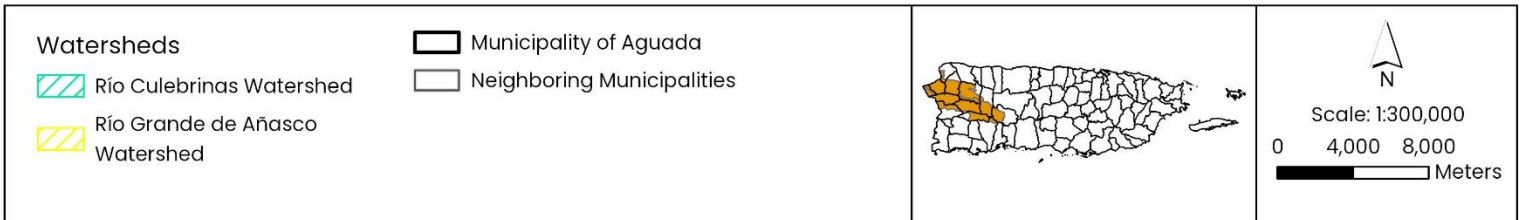
Map 5. Watershed

HYDROGRAPHIC WATERSHEDS

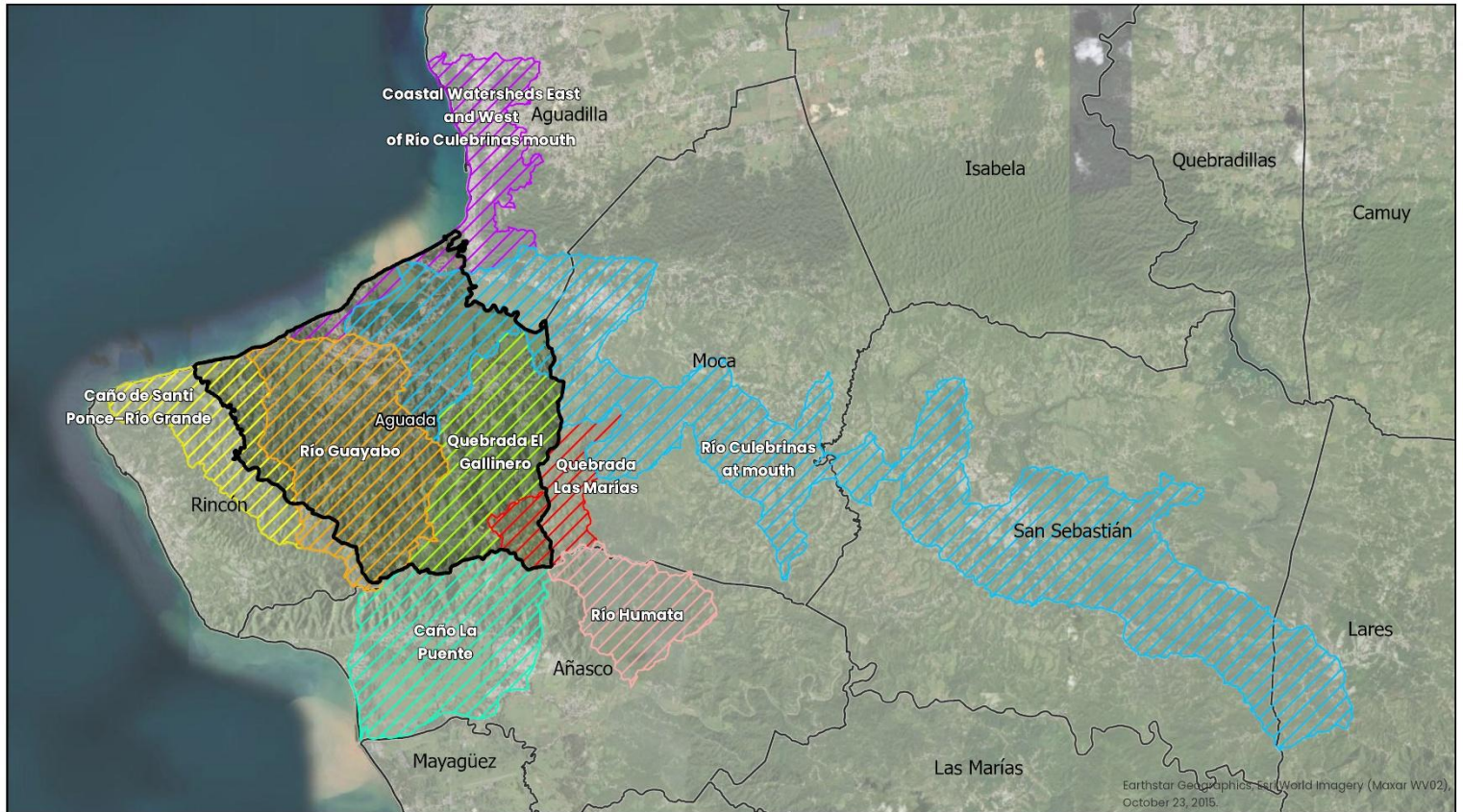


Source: Puerto Rico Planning Board and United States Geological Survey

SPCS PR & VI NAD83



HYDROGRAPHIC SUBWATERSHEDS



Source: Puerto Rico Planning Board and United States Geological Survey

SPCS PR & VI NAD83

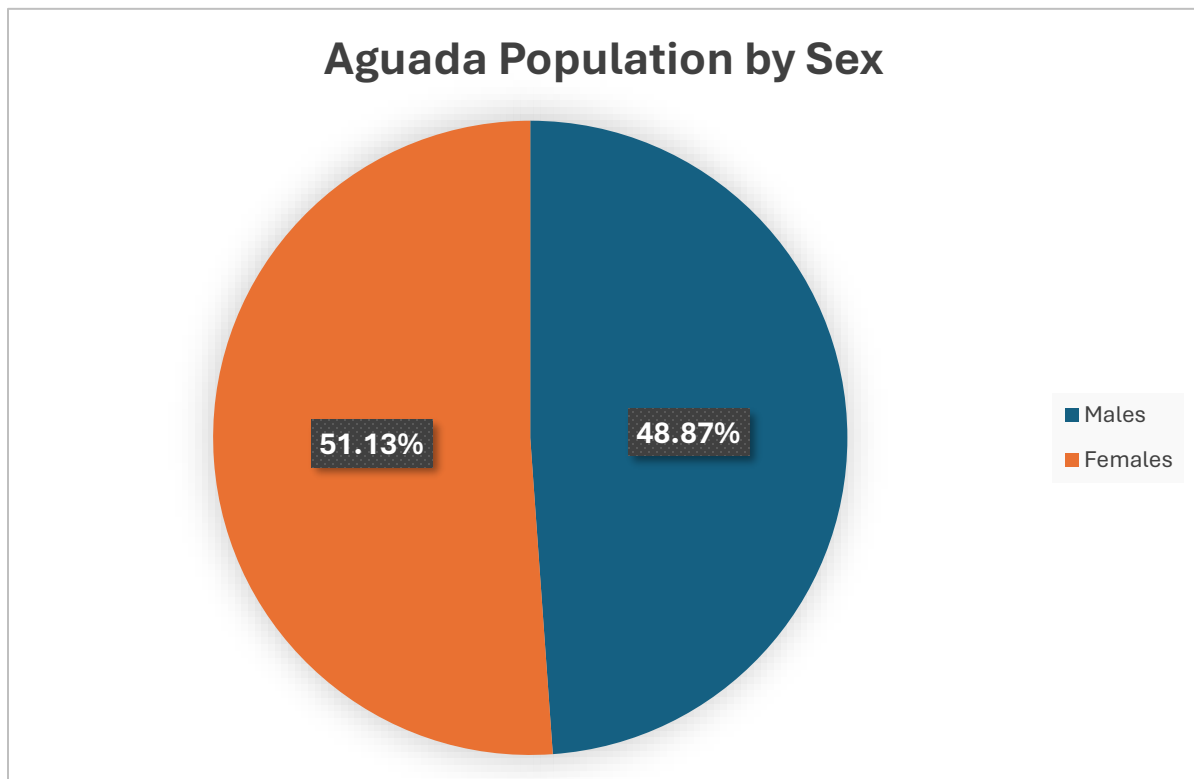


3.4 Demographics

3.4.1 Current Population

According to the 2020–2024 American Community Five-Year Survey (ACS 2024)³ the total population of Aguada is 37,758. Of these, 18,451 persons are male and 19,307 are female. The percentage split is 48.87% male, 51.13% female. The sex ratio is of 95.56 males per 100 females (US Census Bureau, 2025).

Figure 9. Population by Sex (2024 ACS)



According to the 2024 ACS a total of 8,758 people (23%) in Aguada were 65 or older. This constitutes almost a quarter of the total population of Aguada. While 3,782 people (10.00%) of the population are 75 years old or older.

³ Unless otherwise stated, all data and analysis are from the 2024 Five-Year American Community Survey (ACS) Data Set for Aguada.

3.4.2 Age

On the younger age groups, Aguada has 6,478 (17.10%) people that are younger than 19 years. Of those 1,950 (5.20%) are 9 years old or younger. On the elder age groups, Aguada has 8,758 (23.2%) residents who are 65 years of age or older. This LHMP considers people younger than 19 and older than 65 as vulnerable populations due to their increased sensitivity to the effects of natural disasters. As such we find that 15,236 residents of Aguada (40.35 % of the population) are especially vulnerable to the effects of a natural disaster.

The following table distributes the current population of Aguada by age groups as established in Table 5 DP05 ACS Demographic and Housing Estimates of the ACS. The table also compares the data of the 2024 ACS with that of the 2015–2019 ACS (2019 ACS).

Table 5. Population by Age Group 2024 ACS vs 2019 ACS

Age Cohort	Population 2024	Percentage 2024	Population 2019	Percentage 2019	Net change	Rate of change
Under 5 years	1,066	2.80%	1,542	4.10%	-476	-30.87%
5 to 9 years	884	2.30%	2,069	5.50%	-1185	-57.27%
10 to 14 years	2,479	6.60%	1,931	5.10%	548	28.38%
15 to 19 years	2,049	5.40%	2,411	6.40%	-362	-15.01%
20 to 24 years	2,248	6.00%	2,589	6.80%	-341	-13.17%
25 to 29 years	2,476	6.60%	2,499	6.60%	-23	-0.92%
30 to 34 years	2,048	5.40%	2,174	5.70%	-126	-5.80%
35 to 39 years	2,116	5.60%	2,341	6.20%	-225	-9.61%
40 to 44 years	2,753	7.30%	2,355	6.20%	398	16.90%
45 to 49 years	2,307	6.10%	2,493	6.60%	-186	-7.46%
50 to 54 years	2,538	6.70%	2,910	7.70%	-372	-12.78%
55 to 59 years	2,672	7.10%	2,641	7.00%	31	1.17%
60 to 64 years	3,364	8.90%	3,100	8.20%	264	8.52%
65 to 69 years	2,615	6.90%	2,185	5.80%	430	19.68%
70 to 74 years	2,361	6.30%	1,943	5.10%	418	21.51%
75 to 79 years	1,530	4.10%	1,506	4.00%	24	1.59%
80 to 84 years	1,321	3.50%	774	2.00%	547	70.67%
85 years and over	931	2.50%	491	1.30%	440	89.61%
Total	37,758		37,954			

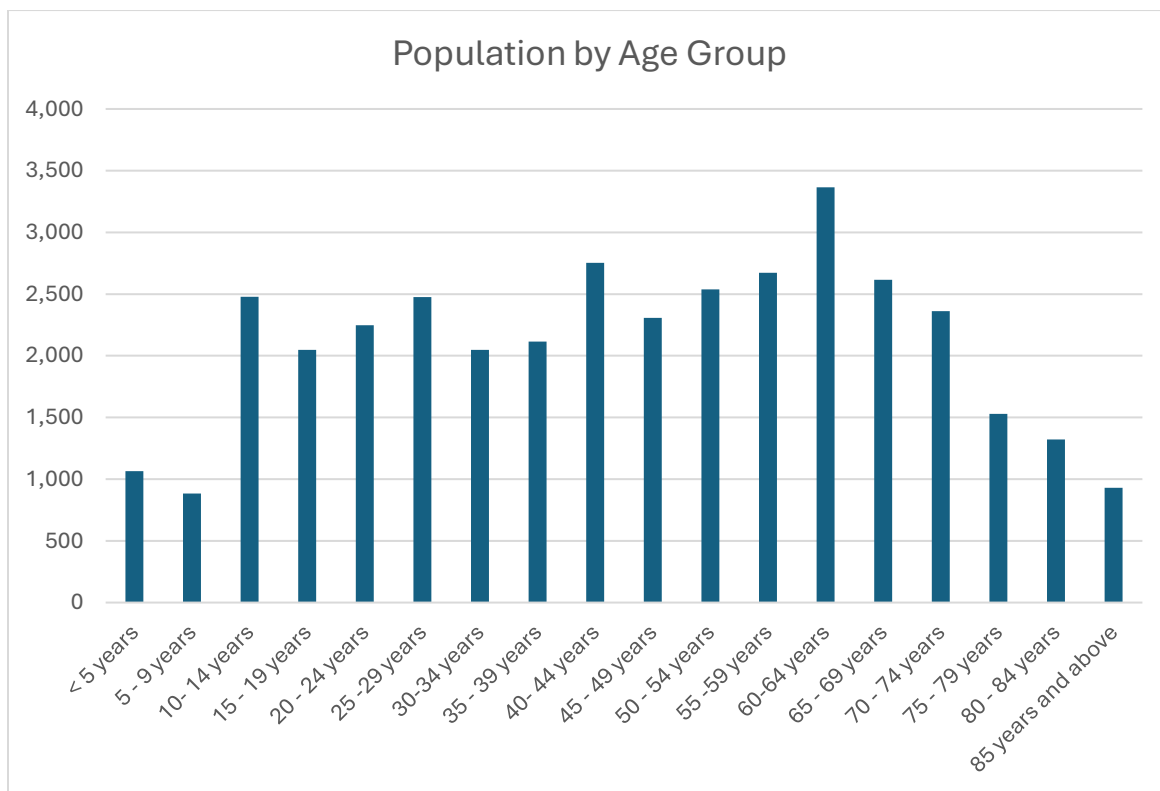
US Census ACS 2020–2024

Table 5 shows that in Aguada the largest negative rate changes occurred in the 5 to

9 years age group (-57.27%), followed by Under 5 years (-30.87%) and 15 to 19 years (-15.01%). In contrast, the largest positive rate changes were seen in the 85 years and over group (+89.61%), followed by 80 to 84 years (+70.67%) and 70 to 74 years (+21.51%). Overall, the municipality experienced a total population decline of -196 people, equivalent to -0.52% between the 2019 and 2024 ACS estimates.

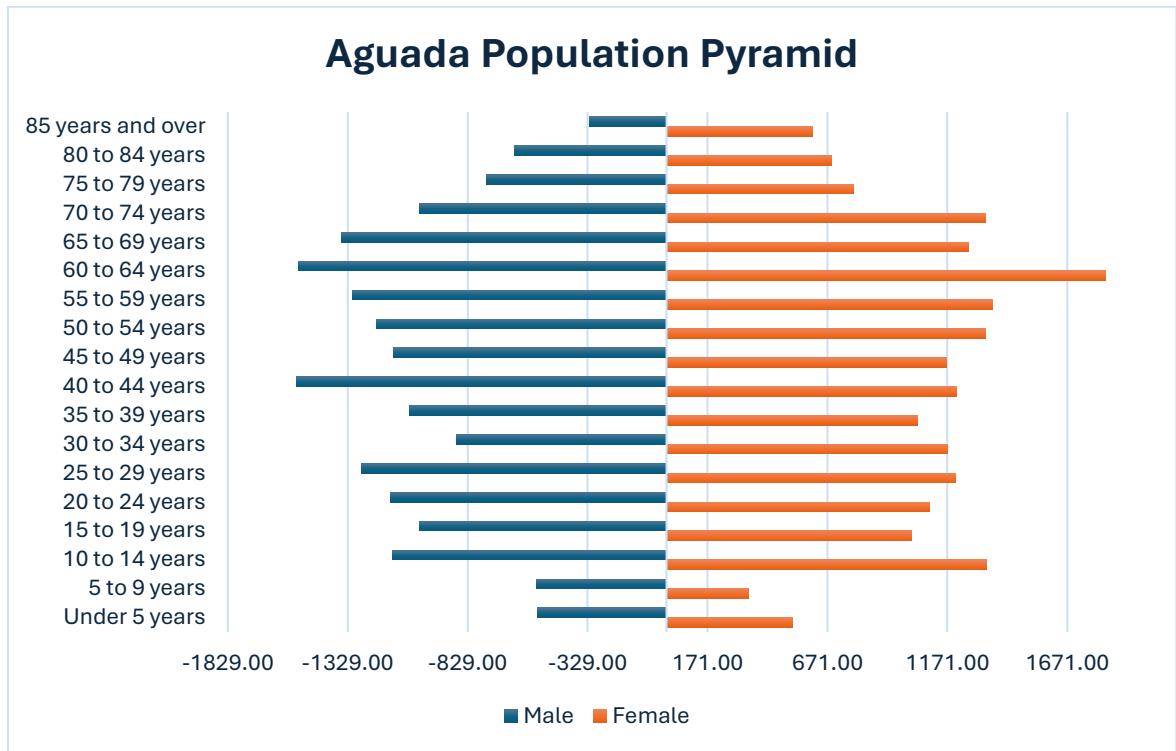
Figure 10 shows the same age group distribution in a bar chart form and Figure 10 displays the population pyramid, showing the distribution of males and females across age cohorts. As shown in figure 11, the pyramid reveals an irregular structure, with a noticeably larger proportion of older adults compared to younger groups, highlighting the municipality's ongoing demographic aging.

Figure 10. Population by Age Group (ACS 2024)



Source: US Census ACS 2020-2024

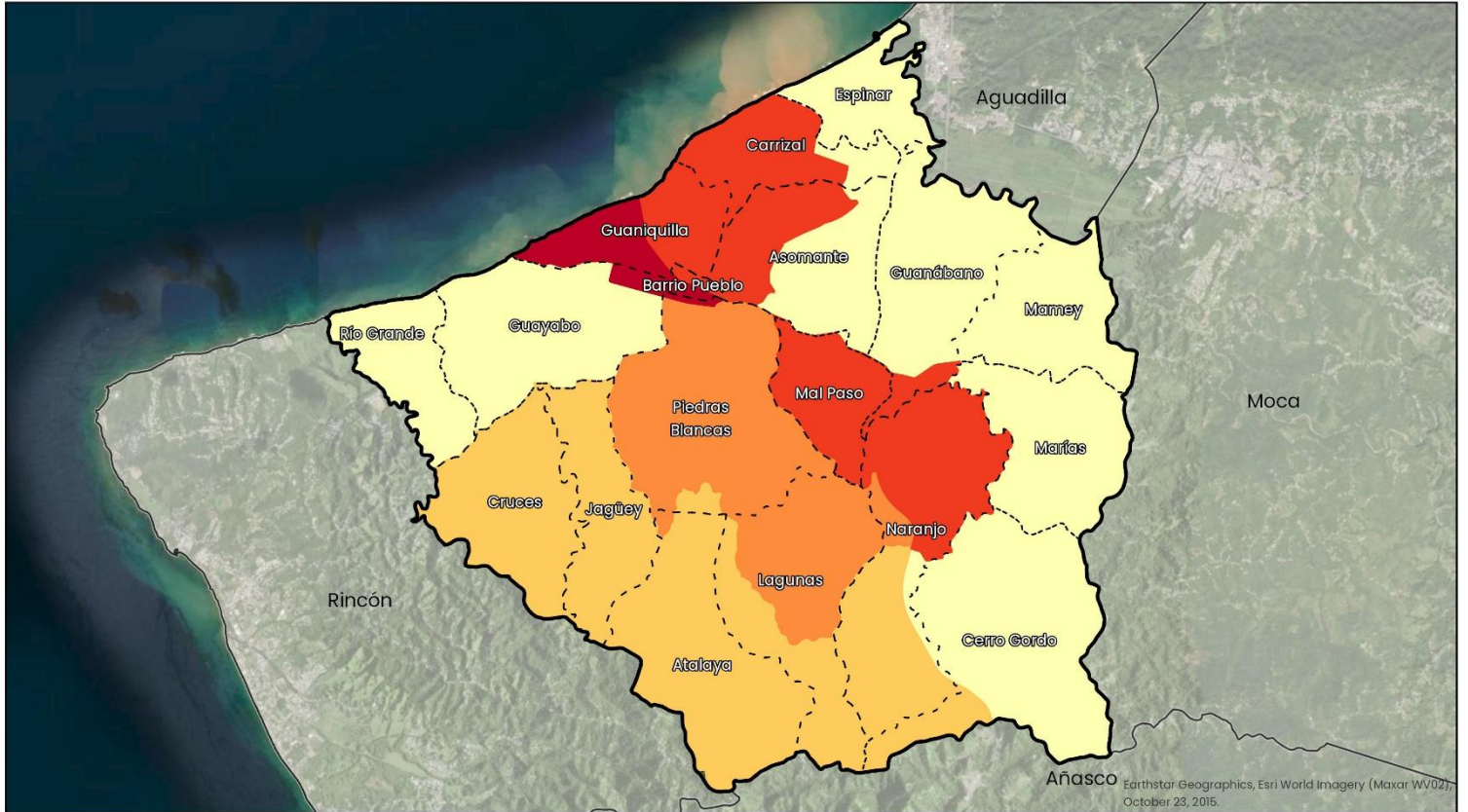
Figure 11: Population Pyramid (2024 ACS)



Source: US Census ACS 2020-2024

Map 7. Population Density by Census Tract

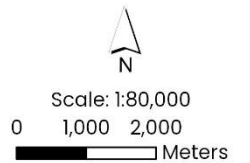
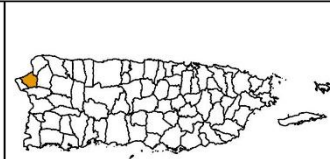
POPULATION DENSITY



Population Density (people/mi²)

885.83 - 946.95
946.96 - 1,059.10
1,059.11 - 1,379.13
1,379.14 - 2,068.20

2,068.21 - 3,135.51
Wards
Municipality of Aguada
Neighboring Municipalities



3.4.3 Socio-economic Characteristics

3.4.3.1 Employment

Table 6 shows the employment status for the municipality according to the 2020 - 2024 Five-Year ACS.

Table 6. Current Labor Force Statistics⁴

Variable ⁵	Estimate	Percentage
Population 16 years and over	33,010	
Civilian Labor Force	12,813	38.80%
In labor force	12,813	38.80%
Employed	12,166	36.90%
Unemployed	647	2.00%
Armed Forces	0	0.00%
Not in Labor Force	20,197	61.20%
Unemployment rate		5.00%

US Census ACS 2020-2024

The census data shows that the population in the labor force for Aguada is lower than population that is not in the labor force (38.80% in labor force vs 61.20% not in labor force). Compared with the 2015-2019 Five-Year ACS the percentage of population in the labor force has decreased (38.80% in 2024 vs 39.80% in 2019). In comparison with the whole Commonwealth of Puerto Rico the municipal population in the labor force is lower (38.80% for Aguada vs 46.40% for Puerto Rico).

The 2024 ACS showed an unemployment rate for the municipality of 5.00%. This represents a decrease regarding the 2015-2019 Five-Year ACS (5.00% in 2024 vs 11.5% in 2019). In comparison to the whole Commonwealth of Puerto Rico, the unemployment rate is higher (5.00% for Aguada vs 10.7% for Puerto Rico).

⁴ US Census Table DP03: Selected Economic Characteristics

⁵ According to the U.S. Census Bureau and the American Community Survey (ACS), the terms labor force and civilian labor force are related but not identical: Civilian Labor Force consists of all noninstitutionalized civilians aged 16 years and older who are either employed (working or temporarily absent from a job), or unemployed (not working but actively seeking work and available to work). The labor force is broader than the civilian labor force. It includes everyone in the civilian labor force (employed, unemployed civilians), plus active-duty members of the U.S. Armed Forces. Institutionalized populations are people in prisons or nursing facilities.

3.4.3.2 Employment by Industry

The following table presents employment by industry within the municipality, comparing data from the 2020–2024 Five-Year ACS with the 2015–2019 Five-Year ACS. The final column reflects the percentage change in employment by industry between the two survey periods.

Table 7. Employment by Industry 2024 ACS vs 2019 ACS

Industry	ACS 2024 Five Year	Percentage 2024	ACS 2019 Five Year	Percentage 2019	Rate Change between 2024 and 2019 ⁶
Agriculture, Forestry, fishing and hunting and mining	103	0.80%	31	0.30%	232.26%
Construction	955	7.80%	1,025	9.10%	-6.83%
Manufacturing	1,131	9.30%	1,077	9.60%	5.01%
Wholesale Trade	301	2.50%	265	2.40%	13.58%
Retail Trade	1,936	15.90%	1,710	15.20%	13.22%
Transportation and warehousing, and utilities	518	4.30%	484	4.30%	7.02%
Information	184	1.50%	250	2.20%	-26.40%
Finance and Insurance, and real estate and rental and leasing	407	3.30%	273	2.40%	49.08%
Professional, scientific, and management, and administrative and waste management services	1,686	13.90%	1,362	12.10%	23.79%
Educational services, health care and social assistance	1,846	15.20%	2,114	18.80%	-12.68%
Arts, entertainment, recreation, and accommodation and food services	1,559	12.80%	1,110	9.90%	40.45%
Other services, except public administration	793	6.50%	837	7.40%	-5.26%
Public administration	747	6.10%	712	6.30%	4.92%

⁶ Rate of percentage change is calculated as *Percentage Change* =
$$\frac{\text{new value} - \text{original value}}{\text{original value}} \times 100$$

Industry	ACS 2024 Five Year	Percentage 2024	ACS 2019 Five Year	Percentage 2019	Rate Change between 2024 and 2019 ⁶
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Total employee Population 16 years and over	12,166		11,250		
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US Census ACS 2020-2024 and US Census ACS 2015-2019

Table 7 shows the following employment characteristics for Aguada:

- The industry with the highest level of employment in Aguada in 2024 is the “Educational services, healthcare and social assistance” industry occupying 15.20% of Aguada’s workforce. This can explain the numerous healthcare facilities that are identified within the jurisdiction of the municipality in the analysis of the Health and Medicine Lifeline in section 3.5.3.
- In comparison with the 2019 survey, we find that “Educational services, health care and social assistance industry” was also the one with the highest level of employment. However, this industry had the highest level of net negative growth among all the industries of Aguada. The percentage rate between 2019 and 2024 represented a delta of -12.68%.
- The other two industries that occupy more than 10% of the employee population are the Retail Trade industry (15.90%) and the Professional, scientific, and management, and administrative, and waste management industry (13.90%).
- The industries that had negative growth between the 2019 and the 2024 surveys are:
 - Educational services, health care and social assistance (-268 individuals or a -12.68 % rate change).
 - Arts, entertainment, recreation, accommodation and food services (449 individuals or a 40.45 % rate change)
 - Public Administration (35 individuals or a 4.92% rate change)
 - Information (-66 individuals or -26.40%).
- The industry that had the highest net growth was Professional, scientific, and management, and administrative and waste management services, with a net increase of 324 individuals. This represents a percentage rate change of 23.79%.
- Other industries that had a positive percentage change rate are:
 - “Agriculture, Forestry, fishing and hunting and mining” (72 individuals or 232.26 % rate of change)
 - “Construction” (-70 individuals or -6.83 % rate of change)
 - “Manufacturing” (54 individuals or 5.01% rate of change)
 - Wholesale Trade (36 individuals or 13.58% rate of change)

- “Retail trade” (226 individuals or 13.22 % rate of change)
- “Transportation and warehousing, and utilities” (34 individuals or 7.02 % rate of change)
- “Finance and Insurance, and real estate and rental and leasing” (134 individuals or 49.08 % rate of change).
- “Professional, scientific, and management, and administrative and waste management services” (324 individuals or 23.79 % rate of change).
- Overall, the employed population of the municipality increased by 916 individuals, this represents a rate change of 8.14% between 2019 and 2024.
- An interesting outlier is the “Agriculture, forestry, fishing and hunting, and mining” industry that had a rate change of 232.26%, however even in 2024 this industry only employs 103 individuals or less than 1% of the employee population.

3.4.3.3 Poverty Level

The table below shows the estimated percentage of poverty status for individuals over the past 12 months. This information is used to evaluate the economic well-being of individuals and families. The table is essential for understanding the economic conditions of different groups and for guiding the development and implementation of policies aimed at reducing poverty as well as the vulnerability of the population.

Table 8. Poverty Level - 2024 ACS

Total Population ⁷	Number of Individual below the poverty level during the last 12 months	Percentage of the Population below the poverty level in the last 12 months
37,602	17,495	46.50%

US Census ACS 2020-2024

3.4.3.4 Income

According to the 2024 ACS the median household income for Aguada was \$21,501 while the mean household income was \$31,531. The following table shows the estimated income and benefits for households in the municipality.

⁷ Note that the census data has a slight discrepancy in the number of total population reported in this dataset and other data sets.

Table 9. 2024 ACS Income and Benefits per Household

Category	Number of Households	Percentage
Less than \$10,000	2,843	21.70%
\$10,000 to \$14,999	1,626	12.40%
\$15,000 to \$24,999	2,866	21.90%
\$25,000 to \$34,999	1,985	15.20%
\$35,000 to \$49,999	1,676	12.80%
\$50,000 to \$74,999	1,013	7.70%
\$75,000 to \$99,999	615	4.70%
\$100,000 to \$149,999	183	1.40%
\$150,000 to \$199,999	203	1.50%
\$200,000 or more	90	0.70%
Total households	13,100	100%

US Census ACS 2020-2024

This table shows that 21.70% of all households in Aguada earn less than \$10,000 per year. While 56.00% of households earn less than \$25,000 per year. In comparison for the 2015-2019 ACS 30.10 % of households earn less than \$10,000 and 64.50% of households earn less than \$25,000.

3.4.3.5 Population with disabilities

Table 10 presents data on individuals living with disabilities based on the 2015-2019 and 2020-2024 American Community Survey (ACS) five-year estimates. The municipality experienced a net increase of 175 people living with a disability, representing a 1.67 percent increase over the period. Growth was concentrated among older residents, with the population aged 65 to 74 years increasing by 6.72 percent and the population aged 75 years and over increasing by 28.76 percent. In contrast, disability counts declined among residents aged 18 to 34 years (-33.69 percent) and 35 to 64 years (-7.50 percent). These findings are relevant to hazard mitigation planning because older adults and people with disabilities often face additional challenges during evacuation, sheltering, response, and recovery from natural hazard events.

Table 10. Population living with disabilities

Age Group	2024	2019	Net change	Rate of change
Under 5 years	0	0	0	0
5 to 17 years	298	258	40	15.50%
18 to 34 years	500	754	-254	-33.69%

Age Group	2024	2019	Net change	Rate of change
35 to 64 years	4,600	4,973	-373	-7.50%
65 to 74 years	2,571	2,409	162	6.72%
75 years and over	2,686	2,086	600	28.76%
Total Population living with a disability	10,655	10,480	175	1.67%

US Census ACS 2020–2024 and US Census ACS 2015–2019

Table 11 Provides information on households in Aguada that receive food assistance, based on data from the 2020–2024 and 2015–2019 American Community Survey (US Census Bureau, 2025).

Table 11. Population receiving food aid

Data Set	2024	2019	Net Change	Rate of Change
Total Households in the municipality	13,100	12,830	270	2.10%
Households receiving food assistance	7,523	6,592	931	14.12%
Percent of Households receiving food assistance	57.40%	51.40%	–	–

US Census ACS 2020–2024 and US Census ACS 2015–2019

As shown in this table the number of households in Aguada receiving food assistance is 7,523. The total number of households receiving food assistance has increased by 14.12% since 2019 ACS. The table shows that 57.40% of households in Aguada receive food assistance and thus can be considered as experiencing food insecurity.

3.4.3.6 Health Insurance Coverage

Table 12 shows the 2020–2024 health insurance coverage for the municipality.

Table 12. 2024 ACS Health Insurance Data

Variable	Estimate	Percentage
Civilian noninstitutionalized population	37,602	
With health insurance coverage	35,691	94.90%
With private health insurance	11,410	30.30%
With public coverage	26,116	69.50%
No health insurance coverage	1,911	5.10%

US Census ACS 2020–2024

The data shows that 1,911 people (5.10%) in Aguada have no health insurance at all. Meanwhile, 69.50% of the civilian noninstitutionalized population depends on public health coverage. This data will be revisited when discussing the hazard of pandemic/epidemic.

3.4.4 Housing Stock and Other Related Details

According to 2024 ACS Aguada had a total of 17,824 housing units of those a total of 4,724 were vacant. This constitutes 26.50% of the total housing stock of the municipality. According to the 2024 ACS of the 13,100 occupied housing units, 9,675 (73.90%) units were occupied by owners and 3,425 (26.10%) by renters.

Table 13 shows the year of construction of the housing units by range.

Table 13. 2024 ACS – Housing Units Year of Construction

Year Structure Built	Housing Units	Percentage
Built 2020 or later	8	0.00%
Built 2010 to 2019	743	4.20%
Built 2000 to 2009	1,693	9.50%
Built 1990 to 1999	1,990	11.20%
Built 1980 to 1989	3,297	18.50%
Built 1970 to 1979	5,979	33.50%
Built 1960 to 1969	3,083	17.30%
Built 1950 to 1959	821	4.60%
Built 1940 to 1949	112	0.60%
Built 1939 or earlier	98	0.50%
Total	17,824	100%

US Census ACS 2020-2024

The 2024 ACS shows that more than half of the housing stock was built between 1970 and 1999. The latest Building Code was adopted by the government of Puerto Rico in 2018, before that the most recent version of the Building Code was adopted in 2011. This means that at least 95.80% of the housing stock was built before the current and immediately before the previous building code.

Finally, Table 14 shows the vehicle available per occupied housing units.

Table 14. 2024 ACS – Vehicle per occupied housing unit

Variable	Occupied Housing Units	Percentage
No vehicle available	1,638	12.50%
1 vehicle available	5,229	39.90%
2 vehicles available	4,384	33.50%
3 or more vehicles available	1,849	14.10%
Total Occupied Housing Units	13,100	

US Census ACS 2020–2024

The 2024 ACS shows that there are 1,638 housing units that do not have available vehicles. This represents a critical matter since the development pattern in the municipality is rural and/or suburban, where vehicular transportation is necessary for mobility.

3.5 Critical Infrastructure

Infrastructure refers to the essential physical and organizational systems that support the effective functioning of a society or economy. It includes critical networks such as transportation systems (roads, bridges, railways), energy generation and distribution, water supply, telecommunications, and other services that sustain economic activity and daily life. Collectively, infrastructure serves as the foundational framework that enables communities and economies to operate reliably and efficiently (NIST, n.d.). Infrastructure is commonly classified into two categories: hard infrastructure and soft infrastructure.

Hard infrastructure refers to the physical facilities and networks that underpin the functioning of a modern society and economy. This includes transportation systems such as roads, bridges, railways, and airports, as well as water systems, electrical grids, and telecommunications networks. These tangible assets enable the movement of people and goods, the distribution of energy and water, and the transmission of information.

Soft infrastructure refers to the institutions, services, and systems that support economic stability, public health, social order, and cultural development. This category includes educational institutions, healthcare systems, law enforcement agencies, emergency response services, parks, and recreational facilities. Unlike hard infrastructure, soft infrastructure is characterized by organizational frameworks and human-centered services that contribute to community well-being and effective

governance.

As described in Section 2.7 FEMA defines Community Lifelines as the most essential services and systems necessary to sustain the uninterrupted operation of critical government and business functions, while also protecting public health, safety, and economic security. These lifelines constitute the fundamental components of a community and once stabilized, enable all other sectors of society to function effectively. During disaster events, any disruption to these lifelines requires immediate and coordinated action to restore stability and reduce cascading impacts. Accordingly, the assessment of existing infrastructure will be conducted in alignment with FEMA's Community Lifelines framework.

3.5.1 Lifeline: Safety and Security

The purpose of the Safety and Security Lifeline is to protect life and property while maintaining social stability during emergency situations. This lifeline focuses on reducing immediate risks to public safety and personal security through the operation of public safety agencies, controlled access to affected areas, and the prevention of crime, civil unrest, and violence. It also encompasses ensuring safety and security at emergency shelters, distribution centers, and other critical facilities during disaster response and recovery operations.



FEMA indicates that disruption of this lifeline can result in social disorder and heightened community vulnerability, making rapid restoration a critical priority. Response actions require close coordination among federal, state, and local agencies, the deployment of security personnel, the implementation of traffic control measures, and the protection of critical infrastructure.

Map 8 identifies facilities associated with the Safety and Security Lifeline within Aguada. These facilities are primarily concentrated near the urban center, with additional facilities distributed throughout the municipality. Their location supports emergency response, public safety operations, and post-disaster recovery activities.

3.5.2 Lifeline: Food, Hydration and Shelter



The Food, Hydration, and Shelter Lifeline is intended to ensure that disaster-affected populations have prompt access to essential necessities, including food, potable water, and safe shelter. This lifeline encompasses the provision of ready-to-eat meals, water distribution, the establishment of temporary shelters, and coordination with governmental and volunteer organizations to meet basic human needs. Disruptions to this lifeline pose an immediate threat to life; therefore, rapid response actions are prioritized to restore food availability and housing stability as quickly as possible.

Aguada has several designated emergency shelters available to support the municipality's sheltering needs during disaster events. These facilities are located in the barrios of Guanábano, Piedra Blancas, Asomante, Jaguey, and Mal paso, and include Escuela Eladio Tirado López, Little School Academy, Escuela Juana Rosario, Escuela Lydia Meléndez, Escuela Epifanio Estrada, and Escuela Anselmo Villarrubia. The distribution of these shelters across multiple barrios helps support emergency shelter operations throughout different sectors of the municipality and provides options for accommodating displaced residents during emergency situations. The presence of shelters in both central and outlying areas enhances the municipality's capacity to provide temporary housing and life-sustaining services to affected populations.

Map 8 identifies facilities associated with the Food, Hydration, and Shelter Lifeline within Aguada. These facilities are concentrated near developed areas and transportation corridors, while additional facilities are distributed throughout the municipality to support emergency sheltering and resource distribution activities during disaster events.

3.5.3 Lifeline: Health and Medicine

The purpose of this lifeline is to ensure the continuity of essential medical services and the protection of public health during emergencies and disasters. It focuses on stabilizing healthcare delivery, ensuring access to hospitals, clinics, medications, and healthcare personnel, and maintaining the capacity to respond effectively to life-threatening conditions



FEMA indicates that disruption of this lifeline can have serious consequences;

therefore, priority actions focus on restoring medical facilities, deploying emergency response teams, ensuring the availability of critical medical supplies, and coordinating efforts among federal, state, and local agencies.

Map 8 identifies facilities associated with the Health and Medicine Lifeline within Aguada. Several facilities are located near the urban center, while others are distributed throughout the municipality, supporting access to healthcare services during emergency and non-emergency conditions.

3.5.4 Lifeline: Energy



Energy Lifeline is designed to ensure the reliable and safe delivery of electricity, gas, and essential fuels during emergencies and disaster events. This lifeline is vital to sustaining the operation of critical facilities and services, including hospitals, water and wastewater systems, telecommunications, and other infrastructure that depend on uninterrupted energy supply.

FEMA recognizes that disruptions to energy services pose a direct threat to life safety and community stability. Accordingly, priority response actions include the rapid restoration of the electrical grid, the deployment of generators to critical facilities, coordination with fuel suppliers, and the implementation of temporary measures to maintain service continuity. Map 8 illustrates the distribution of gas stations within the municipality and indicates a notable lack of fueling facilities in the southwestern portion of the jurisdiction.

Map 8 identifies facilities associated with Energy Lifeline within Aguada. These facilities form part of the infrastructure that supports electrical and fuel services throughout the municipality and are critical for maintaining essential services during disaster response and recovery operations.

3.5.5 Lifeline: Communications

The purpose of this lifeline is to ensure the availability and reliability of essential communication systems during emergencies and disaster events. These systems include telephone networks, internet services, radio, television, and public alert and warning platforms, all of which are critical for coordinating response activities, disseminating timely information, and maintaining communication between authorities and the public.



FEMA indicates that disruption of the Communications Lifeline can severely impair life-saving operations and effective resource management. Accordingly, priority actions include the restoration of telecommunications infrastructure, deployment of temporary communication solutions such as satellite systems, ensuring redundancy within critical networks, and maintaining accessible communication channels for the public.

Map 8 identifies facilities associated with the Communications Lifeline within Aguada. These facilities support emergency communications, coordination activities, public notifications, and information sharing during disaster events.

3.5.6 Lifeline: Transportation



equipment.

The purpose of the Transportation Lifeline is to ensure the safe and efficient movement of people, goods, and essential services during emergencies and disaster events. This lifeline supports the continued operation or rapid restoration of land, air, and maritime transportation routes, enabling access to critical resources such as food, potable water, medical care, and emergency response

FEMA indicates that disruptions to transportation systems directly affect the ability to save lives and distribute essential supplies. Accordingly, priority actions include reopening roadways, repairing damaged bridges, restoring airport and port operations, and coordinating with state and private entities to maintain the logistics chain.

Map 9 illustrates the primary transportation network within the Municipality of Aguada. The municipality is served by PR-2, the principal transportation corridor that provides regional connectivity to neighboring municipalities and the broader western region of

Puerto Rico. Secondary routes, including PR-115 and PR-417, provide east-west connectivity and facilitate access between the urban center, coastal communities, and interior wards. Numerous tertiary roads extend throughout the municipality, connecting residential areas and rural communities. Maintaining the functionality of these transportation corridors is essential for emergency response, evacuation, debris removal, and post-disaster recovery operations.

3.5.7 Lifeline: Hazardous Materials

The purpose of this lifeline is to prevent hazardous material releases, control spills, and protect communities located near industrial facilities, chemical plants, and hazardous materials transportation corridors.



FEMA indicates that disruption or failure of the Hazardous Materials Lifeline can result in severe consequences, including widespread contamination and the impairment of essential services. Accordingly, priority actions include identifying hazardous materials, activating specialized Hazardous Materials (HazMat) response teams, coordinating with federal and state agencies, and implementing rapid response protocols. Although hazardous materials may be present throughout the municipality, incidents involving hazardous materials are more likely to occur within industrial areas.

Map 8 identifies facilities associated with the Hazardous Materials Lifeline within Aguada. These facilities require appropriate emergency planning and coordination to minimize potential impacts associated with hazardous material incidents.

3.5.8 Lifeline: Water Systems



This lifeline highlights the critical role of water infrastructure in disaster response and recovery. Its primary objective is to ensure reliable access to and the timely restoration of drinking water and wastewater services, which are essential to public health, safety, and economic stability. The Water Systems Lifeline is structured around two core components: Potable Water Infrastructure, which includes water intake, treatment, storage, and distribution; and Wastewater Management, encompassing the collection, storage, treatment, and discharge of wastewater. By prioritizing the protection and functionality of water systems, FEMA seeks to maintain

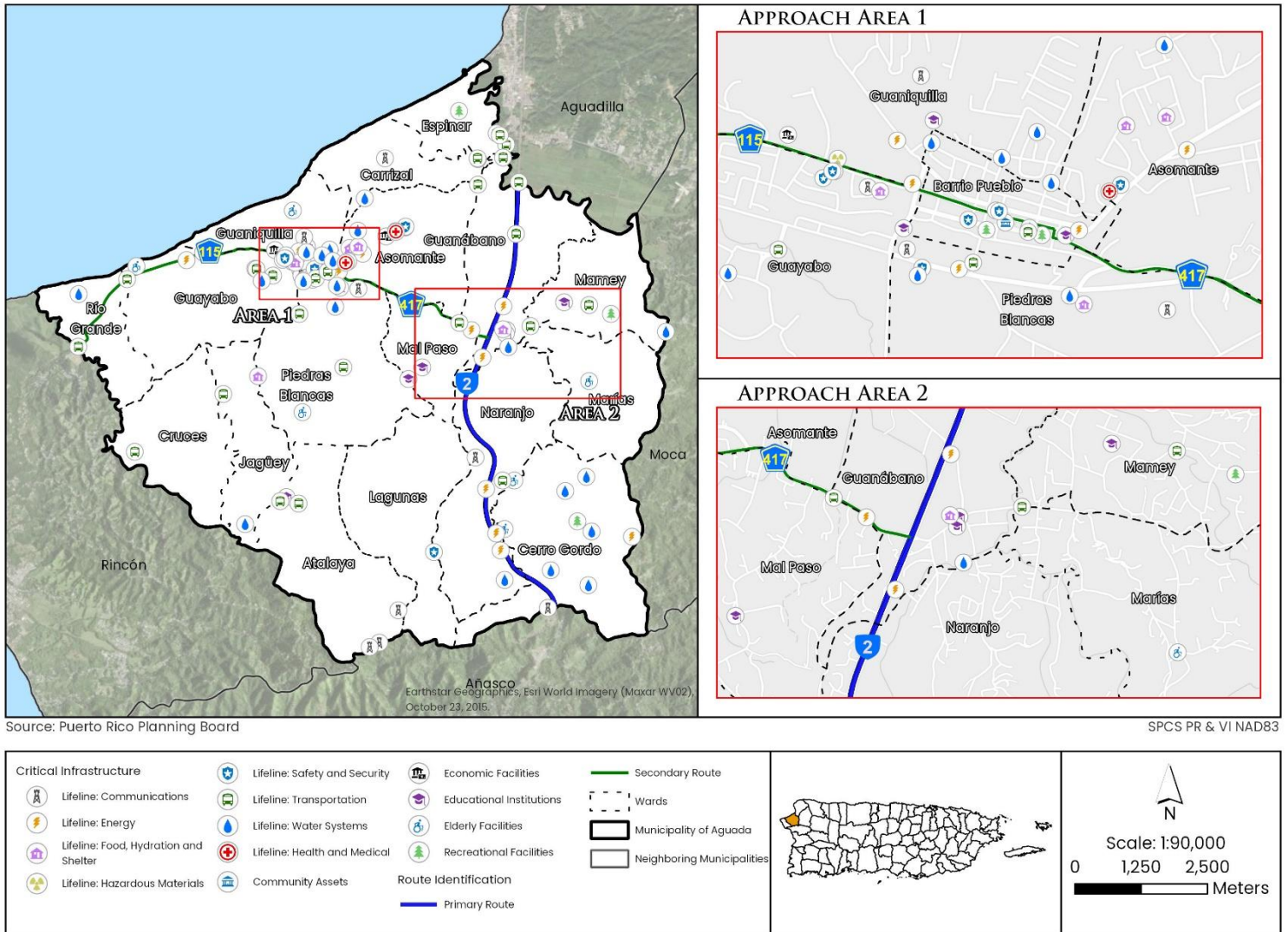
sanitation, support healthcare services, and minimize cascading impacts on food safety and overall community resilience.

Map 8 shows the water system facilities identified within the Municipality of Aguada. Water-related infrastructure is distributed throughout the municipality, including facilities located within the urban center, coastal communities, and interior wards. This distribution supports water supply and wastewater management functions across the municipality while providing service to both urban and rural populations. Protecting these facilities from hazard impacts is essential to maintaining public health, supporting emergency operations, and ensuring continuity of service following disaster events.

Map 8 identifies facilities associated with the Water Systems Lifeline within Aguada. These facilities support potable water and wastewater services that are essential for public health, emergency response, and community recovery following hazard events.

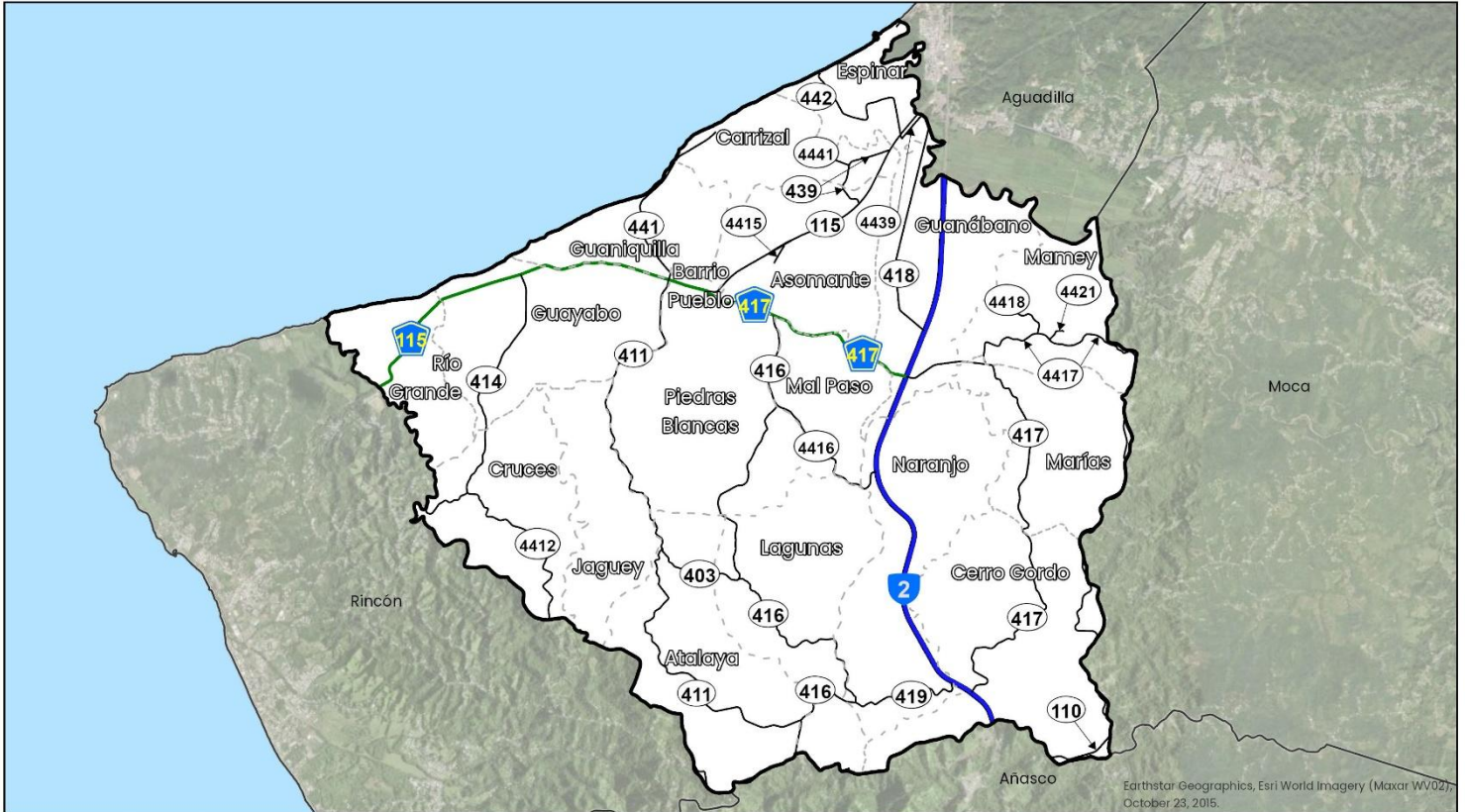
Map 8. Critical Infrastructure by Lifelines

CRITICAL INFRASTRUCTURE BY LIFELINE



Map 9. Roads

ROADS



Source: Puerto Rico Planning Board

SPCS PR & VI NAD83

Route Identification

- Primary Route
- Secondary Route
- Tertiary Route

 Wards

 Municipality of Aguada

 Neighboring Municipalities



Scale: 1:80,000

0 1,000 2,000
Meters

3.6 Recent Development (E1-a)

Hazard mitigation planning must also account for future development conditions. To assess anticipated development trends within the municipality, historical patterns were evaluated using data on construction permits approved between 2020 and 2026. This period begins with the year of approval of the previous hazard mitigation plan. It should be noted that data for 2026 are completed by June 30, 2026.

The data indicates fluctuating construction activity between 2020 and 2026. Permit approvals increased from 60 in 2020 to a peak of 122 in 2021 and remained relatively high in 2022 with 119 permits. Construction activity declined in 2023, when 92 permits were approved, but rebounded in 2024 with 103 permits before decreasing again in 2025 to 99 permits. As of June 30, 2026, 60 permits had been approved. Based on the available data, the Municipality of Aguada records an average of approximately 94 construction permits approved per year during the 2020–2025 period. Table 15 and Figure 12 present the number of constructions permits approved between 2020 and 2026. Maps 10 and 11 illustrate the spatial distribution of these permits. To enhance legibility, the permits are depicted on two separate maps: one showing permits issued from 2020 to 2022, and another showing permits issued from 2023 to 2026. Construction permit activity in Aguada remained distributed throughout the municipality during the 2020–2026 period, reflecting ongoing residential, commercial, and infrastructure development. Permit locations are concentrated primarily in the northern and central portions of the municipality, particularly in and around Barrio Pueblo, Guaniquilla, Guayabo, and neighboring wards, while development activity is also evident in the rural interior. To improve map readability and allow clearer visualization of individual permit locations, the data has been divided into two separate maps: one displaying permits issued from 2020 to 2022 and another displaying permit issued from 2023 to 2026. The spatial distribution of permits provides an indication of recent growth patterns and areas where future development may influence the municipality's exposure to natural hazards.

Table 15. Approved Construction Permits 2020–2026

Approved Construction Permits 2020–2026	
Years	Permits Approved
2020	60
2021	122
2022	119
2023	92
2024	103
2025	99
2026	60

Source: Puerto Rico Planning Board

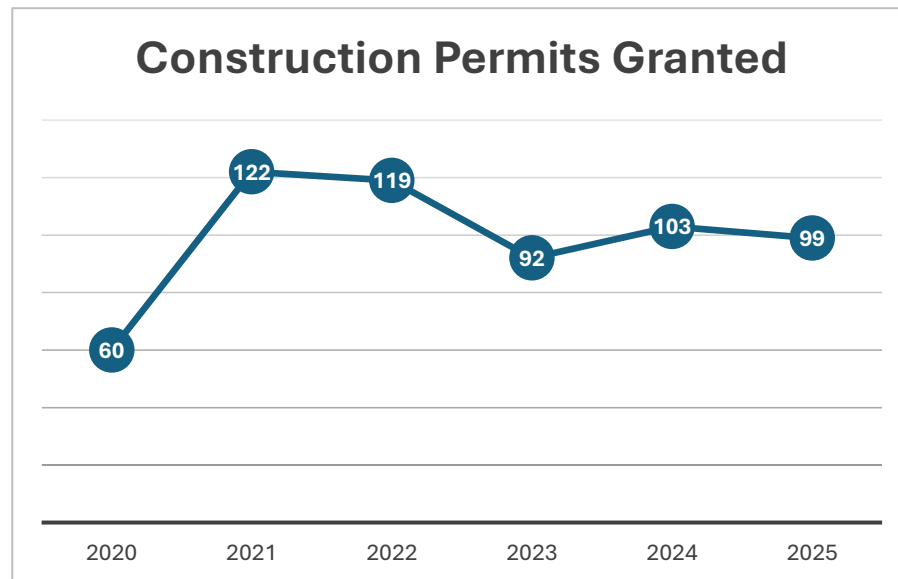
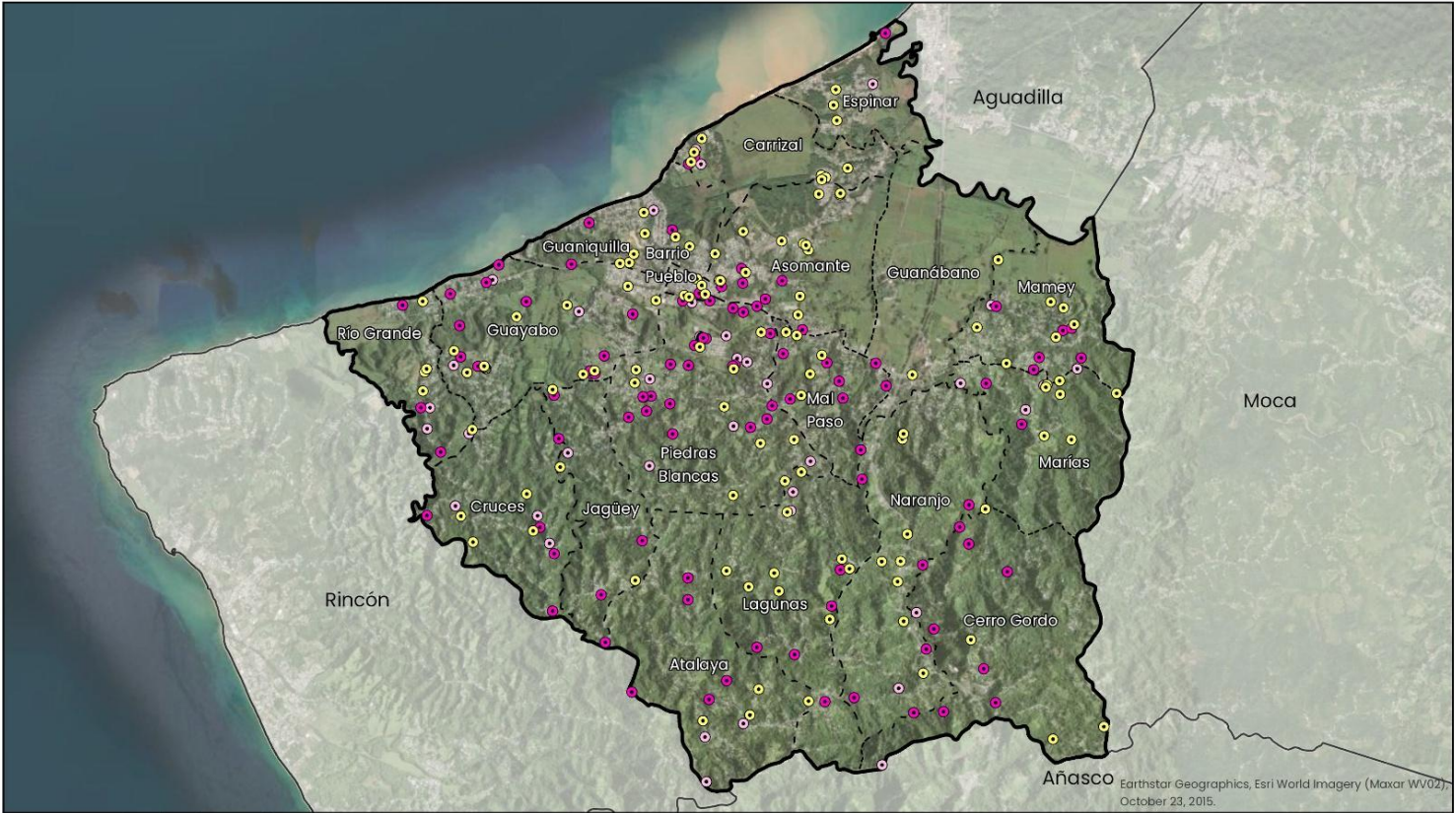


Figure 12. Approved Construction Permits 2020–2025

RECENT DEVELOPMENT 2020 - 2022

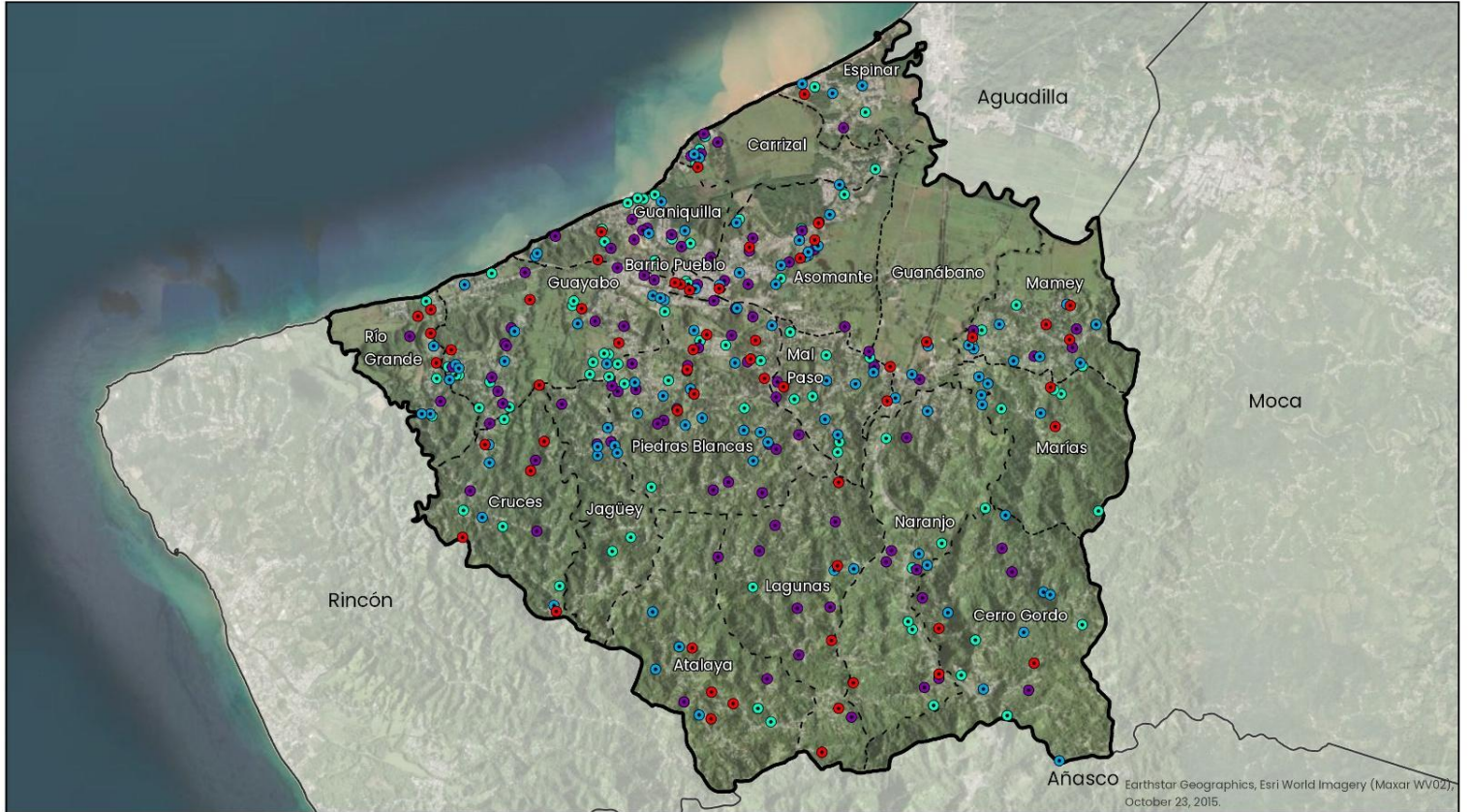


Source: Puerto Rico Planning Board

SPCS PR & VI NAD83



RECENT DEVELOPMENT 2023 - 2026



Source: Puerto Rico Planning Board

SPCS PR & VI NAD83

Construction Permits Granted

Year Created and Count

2023 (92)

2024 (103)

2025 (99)

2026 (58)

Wards

Municipality of Aguada

Neighboring Municipalities



Scale: 1:80,000

0 1,000 2,000

Meters

4. Hazard Profiles and Risk Assessment

4.1 Note on the Discussion of Hazards

The 2020 LHMP divided the discussion of the considered hazards into two separate and non-continuous sections. This arrangement made the analysis of the hazard cumbersome since the reader had to go back and forth between two different sections of this large document. In order to improve this, this new LHMP discusses both the profile of the hazard and the risk associated in one single section.

4.2 Regulatory Requirements

Federal regulation 44 C.F.R. § 201.6(c)(2) establishes the requirements related to hazard identification and risk assessment for LHMP. The Plan LHMP must include the following:

- An assessment that provides the basis for identifying the proposed activities aimed at reducing losses associated with the identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses related to the identified hazards. The hazard assessment must include:
 - A description of the type, location, and extent of all natural hazards that may affect the jurisdiction. It must contain information on previous occurrences of hazard events and the probability of future hazards.
 - A description of the jurisdiction's vulnerability to the identified hazards. This description must include a comprehensive summary of each hazard and its impact on the community. This Plan must describe vulnerability in terms of:
 - The number of existing structures, infrastructure, and critical facilities located within identified hazard areas;
 - An estimate of the potential monetary losses to structures identified as vulnerable, along with a description of the methodology used to prepare the estimate; and, lastly,
 - A general description of land use and development patterns within the community so that mitigation options can be considered in future land-use decisions.
 - A description of all structures insured under the National Flood Insurance Program (NFIP) that have experienced repetitive damage from different

flood events. It must explicitly indicate whether the community participates in the NFIP and complies with its regulations. It must also include a table showing repetitive property losses along with a table of NFIP claims and losses.

4.3 Hazards that can Affect the Municipality

To determine the hazards to be addressed in this LHMP, the Municipality reviewed and integrated information from the 2021 Puerto Rico State Hazard Mitigation Plan, the 2020 Aguada Local Hazard Mitigation Plan, and the latest LHMP's of the municipalities that share a boundary with Aguada. The following table summarizes the hazards addressed in these Hazard Mitigation Plans. A check mark "✓" indicates that the hazard was included in the corresponding plan, while an "✗" denotes that it was not.

Table 16. Historical Hazards Inventories

Hazard	2026 PRSHMP	2020 Aguada LHMP	Neighboring Municipalities
Earthquake/Liquefaction	✓	✓	✓
Landslides	✓	✓	✓
Tsunami	✓	✓	✓
Flooding	✓	✓	✓
Storm Surge	✓	✓	✓
Coastal Erosion	✓	✓	✓
Sea Level Rise	✓	✓	✓
Extreme Winds Hazard	✓	✓	✓
Extreme Heat	✓	✓	✓
Drought	✓	✓	✓
Wildfire	✓	✓	✓
Pandemic/Epidemic	✓	✗	✗

After reviewing the hazard profiles contained in these documents, the Municipality of Aguada determined that the following hazards shall be assessed and evaluated as part of the 2026 LHMP:

Table 17. Hazards to be included in the Aguada 2026 LHMP

Hazard	Included in Aguada 2026 LHMP?	Comments
Earthquake	✓	It is included given Puerto Rico's location

Hazard	Included in Aguada 2026 LHMP?	Comments
		among major fault lines and the 2020 Seismic activity.
Landslides	✓	It is included given the high propensity for landslides in Aguada's territory.
Tsunami	✓	It is included given Puerto Rico's location among major fault lines and the 2020 Seismic activity.
Flooding	✓	It is included given the presence of extensive flood zones in the municipality that host critical infrastructure.
Tropical Cyclones/Extreme Winds	✓	It is included given that the southeastern region of Puerto Rico has been the most recurrent point-of-entry for hurricanes that make landfall in Puerto Rico in recorded history. (National Oceanic and Atmospheric Administration, 2026)
Storm Surge	✓	It is included given the presence of extensive coastal flood plains and critical infrastructure that is exposed to this hazard.
Long – Term Coastal Modification	✓	It is included given there is critical infrastructure that is exposed to this hazard.
Extreme Winds Hazard	x	Included as part of the discussion on tropical cyclones.
Extreme Heat	✓	Included in the previous LHMP. Higher-than-average temperatures and the increasing frequency of extreme heat events warrant its continued inclusion in the LHMP.
Drought	✓	It is included given the 2014-2016 droughts and recent periods of moderate drought
Wildfire	✓	Periods of drought, high temperatures, and combustible vegetation have demonstrated the municipality's vulnerability to fires that threaten public safety, property, and natural resources
Pandemic/Epidemic	✓	The municipality of Aguada included this in the previous AHMP. It will be considered by the LHMP update given the COVID -19 emergency declaration of 2020.
High Hazard Potential Dam	x	This risk was not evaluated in this plan as the municipality has no direct risk exposure

Hazard	Included in Aguada 2026 LHMP?	Comments
		within its territory or from neighboring municipalities.

For the rest of this document, the hazards shall be evaluated in the following order:

Table 18. Order of Hazards to be Assessed

Classification	Hazard
Geological Hazards	Earthquake
	Landslides
	Tsunami
Hydrological Hazards	Flooding
Meteorological Hazards	Tropical Cyclone/ Extreme Winds
	Storm Surge
	Extreme Heat
	Drought
Environmental Hazards	Wildfire
	Long-Term Coastal Modifications
Biological Hazards	Pandemic/Epidemic
Anthropogenic Hazards	High Hazard Potential Dam

4.4 Chronology of Events

To prevent duplication of data and for easy reference in the discussion of each hazard profile the reader will find a chronology of events in the discussion of the hazard itself.

4.5 Risk Assessment Methodology

This section describes the methodologies employed to evaluate the identified hazards. Given that each hazard presents distinct characteristics, data needs, and levels of uncertainty, multiple analytical approaches were utilized to ensure a thorough, accurate, and comprehensive risk assessment.

4.5.1 HAZUS 6.1

HAZUS is a Geographic Information System (GIS)–based risk assessment tool

developed by FEMA to estimate potential losses associated with natural hazards. The software applies scientific modeling and spatial datasets to evaluate the impacts of events such as earthquakes, floods, hurricanes, and tsunamis on buildings, infrastructure, population, and the local economy. HAZUS generates detailed estimates of physical damage, economic losses, and social consequences, thereby supporting hazard mitigation planning, emergency preparedness, and recovery efforts. By integrating data on hazard intensity, exposure, and vulnerability, HAZUS enables decision-makers to prioritize mitigation strategies and allocate resources effectively. The following hazards were evaluated using the HAZUS 6.1 platform:

- Earthquake
- Tropical Cyclone/ Extreme Wind
- Flooding
- Tsunami

4.5.2 Alternative GIS modeling

Certain hazards are not currently modeled in HAZUS; however, they can be evaluated using alternative GIS-based techniques. ESRI® ArcGIS Pro™ 3.6 was utilized to assess hazard vulnerability by incorporating digital risk datasets and the hazard information database previously described. Using these spatial data layers, vulnerability was estimated by identifying the number of critical facilities and buildings located within hazard-prone areas. It is important to note that this method may overestimate exposure levels. In this LHMP, the following hazards were assessed using this GIS-based approach:

- Landslides
- Storm Surges

4.5.3 Stochastic Risk Assessment

The stochastic risk assessment methodology was applied to evaluate hazards that are not addressed by existing hazard models or GIS-based analyses. This method is particularly appropriate for hazards that lack defined geographic boundaries and therefore cannot be reliably examined through spatial analysis. The approach allows for the incorporation of estimated annual losses and impact data; however, the accuracy of the results is highly dependent on the availability and quality of the underlying datasets.

In the case of this LHMP, the hazards evaluated using this methodology are:

- Extreme Heat
- Drought
- Wildfire
- Pandemic/Epidemic
- Long-Term Coastal Dynamics

This methodology is particularly appropriate for hazards that lack clearly defined geographic boundaries and therefore cannot be evaluated through GIS-based analysis. It allows for the incorporation of estimated annual losses and impact data; however, the accuracy of the assessment is highly dependent on the availability and quality of the underlying datasets.

4.6 Earthquake

4.6.1 Description (B1-a)

An earthquake is a sudden movement of the Earth's crust generated by seismic waves that propagate outward in all directions from the focus, or point of origin (FEMA, 1997). The focus is the location within the Earth where the displacement of rocks along a fault initiates, while the epicenter refers to the point on the Earth's surface situated directly above the focus (Puerto Rico Seismic Network, 2019). Earthquakes may occur due to changes in pressure within the Earth's crust, including tectonic plate movement, rock rupture, volcanic activity, landslides, or the collapse of underground cavities.

Most earthquakes result from the release of accumulated stress generated by the displacement of rocks along faults within the Earth's outer crust. These faults are generally located along the boundaries of the planet's major tectonic plates. The highest levels of tectonic instability occur at plate margins where slow, opposing movements create substantial pressure due to plates traveling in different directions and at varying speeds. This deformation along plate boundaries causes stress to build in the surrounding rock. When the accumulated stress surpasses the strength of the rock, a rupture occurs, releasing stored energy in the form of seismic waves that propagate outward and produce an earthquake (NMEAD, 2021).

Earthquakes can impact extensive geographic areas, causing tens of billions of dollars in property damage, significant loss of life, numerous injuries, and widespread disruption to the social and economic stability of affected communities. Most structural damage and earthquake-related fatalities result from building collapse triggered by ground shaking (NMEAD, 2021). The severity of impacts depends on the

amplitude and duration of seismic shaking, which are influenced by factors such as earthquake magnitude, proximity to the fault rupture, and the local and regional geologic conditions (NMEAD, 2021). Additional hazards associated with earthquakes include landslides where soil and rock masses move downslope and liquefaction, a process in which saturated soils lose their rigidity and behave like a fluid. Liquefaction can cause foundations and structures that rely on soil stability to shift, tilt, or collapse. Puerto Rico is located near the boundary between the North American and Caribbean tectonic plates, within a subduction zone where one plate gradually descends beneath the other. This tectonic environment is characterized by significant seismic activity and lateral displacement. The relative movement between these two plates is approximately 2 centimeters per year (Puerto Rico Seismic Network, 2019). According to the Puerto Rico Seismic Network, seismic activity in the region is concentrated in eight (8) primary zones:

- The Puerto Rico Trench to the North,
- The North and South Slope Faults of Puerto Rico,
- The “Sombrero Zone”, to the Northeast,
- The Mona Passage to the West
- The Mona Canyon to the West,
- The Virgin Islands and Anegada depressions to the East,
- The Muertos trough to the South,
- In the southwest of Puerto Rico

To describe earthquake size, seismology uses three (3) primary terms: intensity, magnitude, and ground acceleration. Intensity measures the level of shaking experienced by structures and the natural environment at a specific location. It varies based on the distance from the earthquake’s focus and the duration of the shaking. Magnitude refers to the amount of energy released during the event, as recorded by seismometers. Ground acceleration expresses the force of the seismic waves acting on the ground and is commonly used to characterize the severity of an earthquake (PRSN, 2019).

Earthquakes can generate a variety of secondary hazards, including liquefaction, landslides, seismic wave amplification, and tsunamis. For the purposes of this analysis, the primary secondary hazard of concern is earthquake-induced liquefaction, as it is a condition for which mitigation strategies can be effectively developed once susceptible areas are identified and mapped. Liquefaction refers to the process in which certain saturated soils temporarily lose their structural strength and behave like a dense fluid, significantly reducing their load-bearing capacity (PRSN, 2019). Liquefaction typically occurs in areas underlain by medium- to fine-grained sandy

soils that are saturated with water and of relatively recent geologic origin. These conditions are most found along river margins and within Quaternary (Q) alluvial deposits. Another secondary hazard associated with earthquakes is the amplification of seismic waves. Seismic wave amplification occurs in thick alluvial deposits where seismic waves decelerate, increasing their oscillation and causing the ground to experience stronger and more prolonged shaking.

4.6.1.1 Affected Area (B1-b)

The following maps measure the spectral acceleration and spectral displacement in HAZUS run scenarios.

Spectral Acceleration

Spectral Acceleration is measure used mainly in earthquake engineering to describe how strongly the ground motion from an earthquake would accelerate a structure with a specific natural period. This measure answers the question “If a building (or any structure) vibrates naturally at a certain period, how much acceleration would it experience during an earthquake?” or how hard the ground is pushing on the building at a specific vibration period? The higher the spectral acceleration, stronger the forces acting on the structure will be, which can cause structural failure if the building isn’t designed for it (USGS, 2019).

Spectral Displacement

Spectral Displacement measures how far a structure is expected to move (deform) during an earthquake, based on its natural vibration period and damping in other words, it answers: “For a building with a given natural period, what is the maximum displacement it would experience during earthquake shaking?” (National Institute of Building Sciences, 2020).

Furthermore, the maps below show the Hazus scenario for .03 seconds and 1.0 seconds. The difference relates to how an earthquake impacts different types of structures based on the natural vibration period the building. The maps showing the 0.3-second scenario can affect buildings that are short, stiff structures like 1 or 2-story buildings. These buildings are rigid, so they vibrate quickly when the ground shakes. While the 1.0-second scenario that is more important for buildings are taller, more flexible structures, like mid- to high-rise buildings. These buildings are taller and less stiff and therefore sway more slowly (over a longer period) during an earthquake

(FEMA, Hazus Earthquake Model User Guidance, 2024).

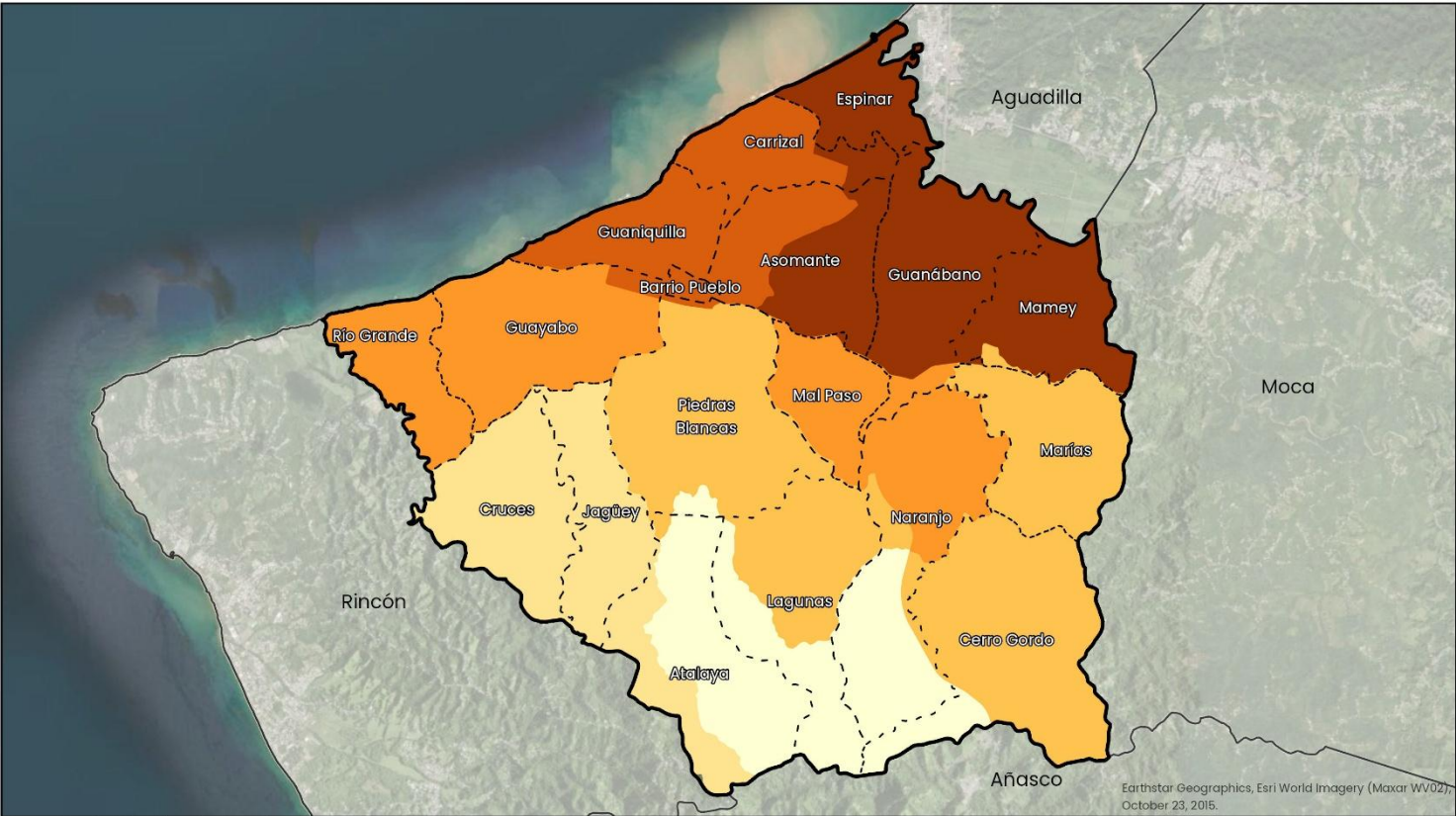
Map 12 illustrates spectral acceleration at a 1.0-second period. Spectral acceleration represents the intensity of ground shaking that structures may experience during an earthquake. The map indicates spatial variations in expected ground motion throughout the municipality, with some areas exhibiting higher acceleration values than others. Areas with higher spectral acceleration may be subject to stronger earthquake forces and, therefore, may experience greater impacts on structures and infrastructure.

Map 13 illustrates spectral acceleration at a 0.3-second period. The map provides an additional representation of expected earthquake ground motion using a different structural response period. Similar to the 1.0-second scenario, the map shows variations in ground-shaking intensity across the municipality that can affect the performance of different types of structures during an earthquake event.

Maps 14 and 15 illustrate spectral displacement at 1.0-second and 0.3-second periods, respectively. Spectral displacement represents the expected movement of structures during earthquake ground shaking. These maps identify areas where greater structural displacement may occur and provide additional information for evaluating potential earthquake impacts. Together, the spectral acceleration and spectral displacement analyses help characterize the relative distribution of seismic hazard throughout the municipality and support the identification of areas that may require additional consideration in future mitigation efforts.

Map 12. Earthquake: Spectral Acceleration at 1.0 sec (g)

EARTHQUAKE: SPECTRAL ACCELERATION AT 1.0 SEC (G)



Source: Puerto Rico Planning Board and Hazus 6.1 Output

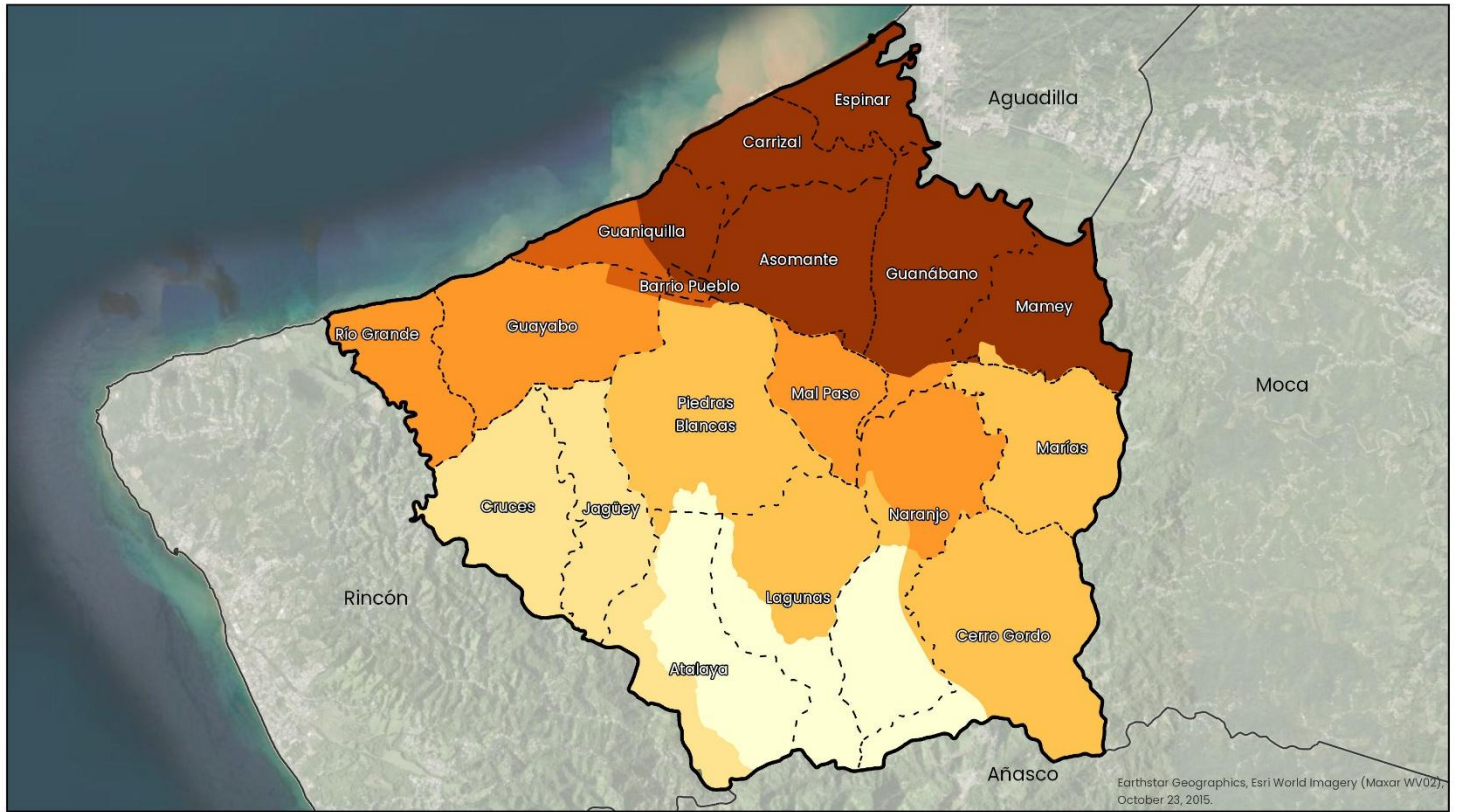
Earthstar Geographics, Esri World Imagery (Maxar WV02), October 23, 2015.

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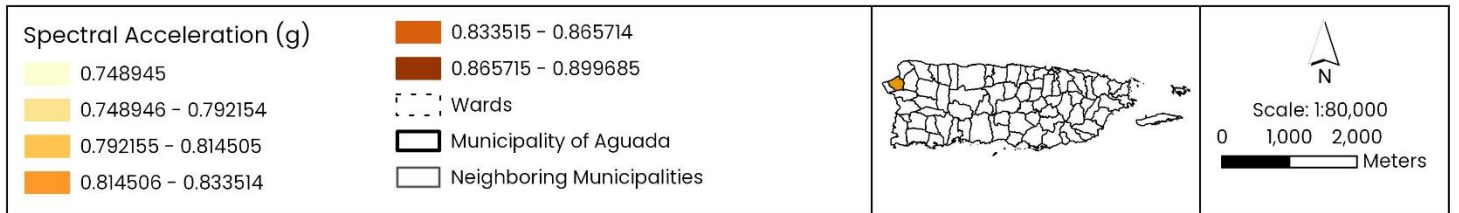
Map 13. Earthquake: Spectral Acceleration at 0.3 sec (g)

EARTHQUAKE: SPECTRAL ACCELERATION AT 0.3 SEC (G)



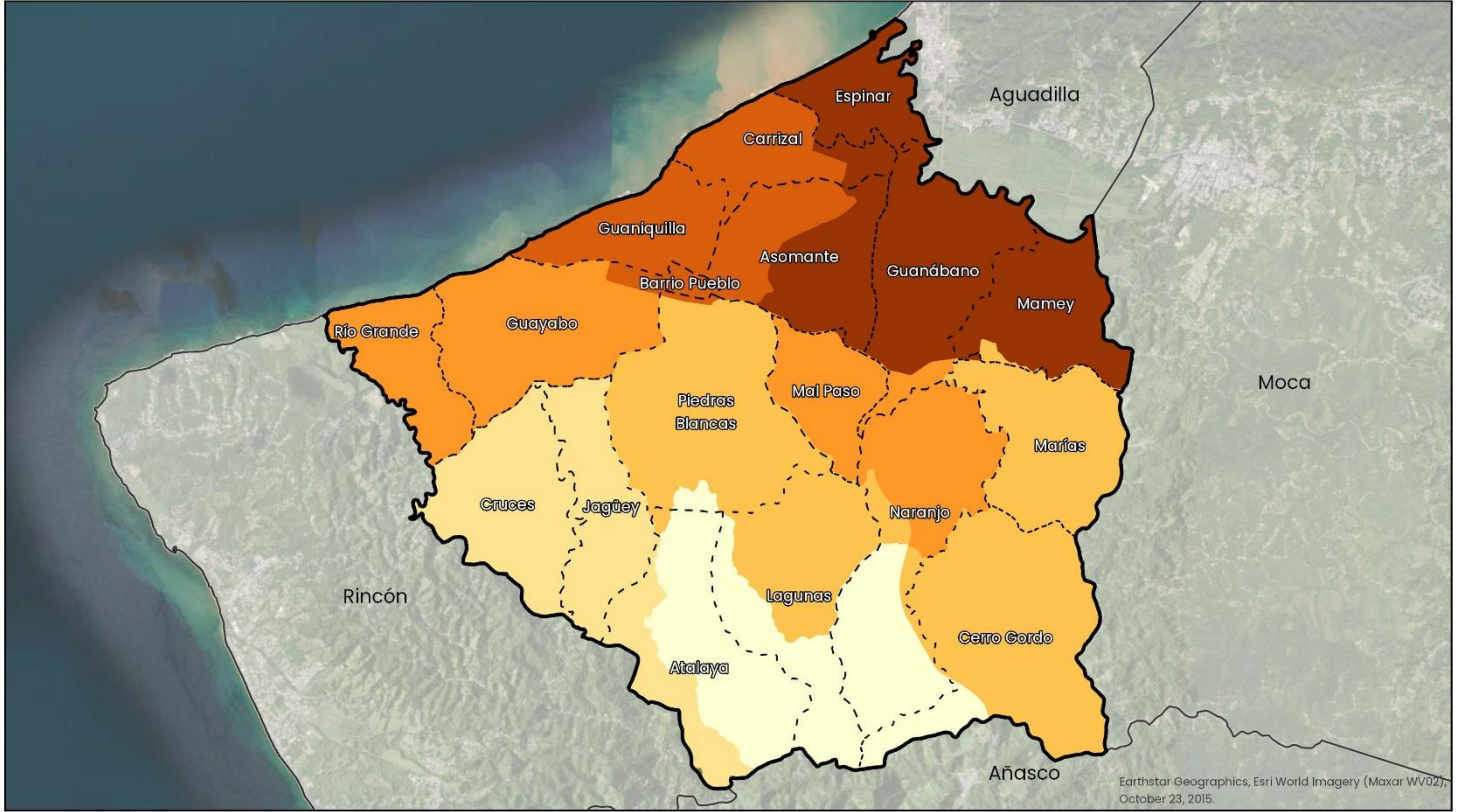
Source: Puerto Rico Planning Board and Hazus 6.1 Output

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Map 14. Earthquake: Spectral Displacement at 1.0 sec (in)

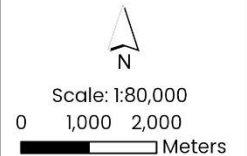
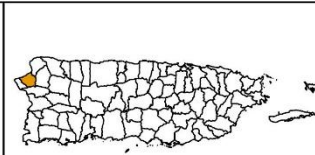
EARTHQUAKE: SPECTRAL DISPLACEMENT AT 1.0 SEC (IN)



Spectral Displacement (in)

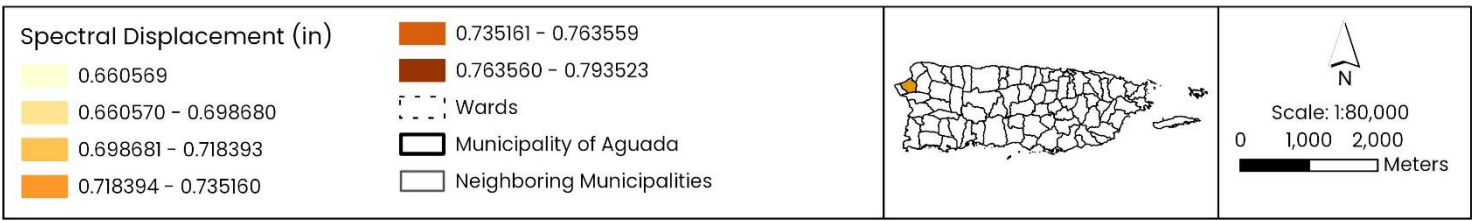
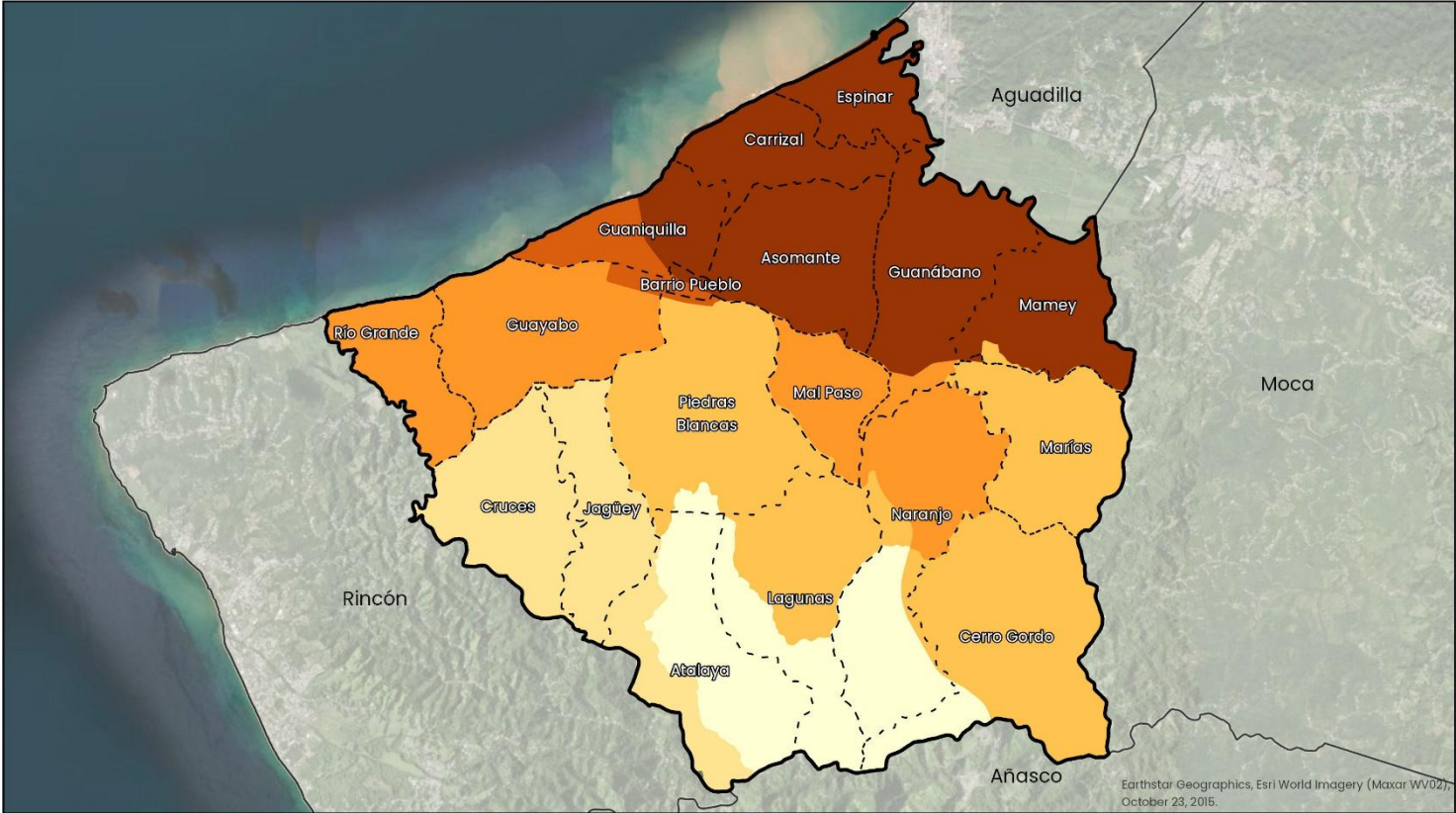
2.908774
2.908775 - 3.269804
3.269805 - 3.377033
3.377034 - 3.517664

3.517665 - 3.935840
3.935841 - 4.111689
Wards
Municipality of Aguada
Neighboring Municipalities



Map 15. Earthquake: Spectral Displacement at 0.3 sec (in)

EARTHQUAKE: SPECTRAL DISPLACEMENT AT 0.3 SEC (IN)



4.6.1.2 Risk Magnitude (B1-c)

The size of an earthquake, commonly associated with the Richter Scale, is widely recognized but often misunderstood. The concept of a logarithmic magnitude scale was first introduced by Charles Richter in the 1930s to measure earthquakes in Southern California using high-frequency recordings from nearby seismograph stations. This original scale, designated as ML where “L” stands for “local” eventually became known as the Richter magnitude.

As global seismic monitoring networks expanded, it became evident that the Richter method was accurate only within specific frequency and distance ranges. To accommodate a broader range of seismic signals recorded worldwide, additional magnitude scales were developed as extensions of Richter’s original concept, including the body-wave magnitude (M_b) and the surface-wave magnitude (M_s). Each of these scales applies to a particular frequency range and type of seismic waves, and within their respective valid ranges, they provide magnitudes equivalent to the Richter scale (USGS, 2024).

Due to the limitations of the ML, M_b , and M_s scales, a more universally applicable scale moment magnitude (M_w) was developed. For large-magnitude earthquakes, M_w provides the most accurate and reliable estimate of earthquake size.

Moment is a physical quantity proportional to the amount of slip that occurs along a fault multiplied by the area of the fault surface that undergoes rupture. It reflects the total energy released by an earthquake. Moment can be derived from seismogram data and geodetic measurements and subsequently converted into a magnitude value using a standardized formula. The resulting measure, known as moment magnitude, provides a consistent and comparable estimate of earthquake size across the full range of magnitudes a capability that earlier scales do not offer (USGS, 2024). Table 19 below shows the Moment – Magnitude scale.

Table 19. *Moment - Magnitude Scale*⁸

Range	Description
Mw < 3.0	Usually not felt by people.
Mw 3.0 – 4.9	Minor earthquakes, often felt but rarely cause damage.
Mw 5.0 – 5.9	Moderate can cause slight damage to poorly built structures.
Mw 6.0 – 6.9	Strong can cause significant damage in populated areas.
Mw 7.0–7.9	Major, serious damage over large areas.
Mw ≥ 8.0	Great earthquakes, catastrophic damage over very large regions.

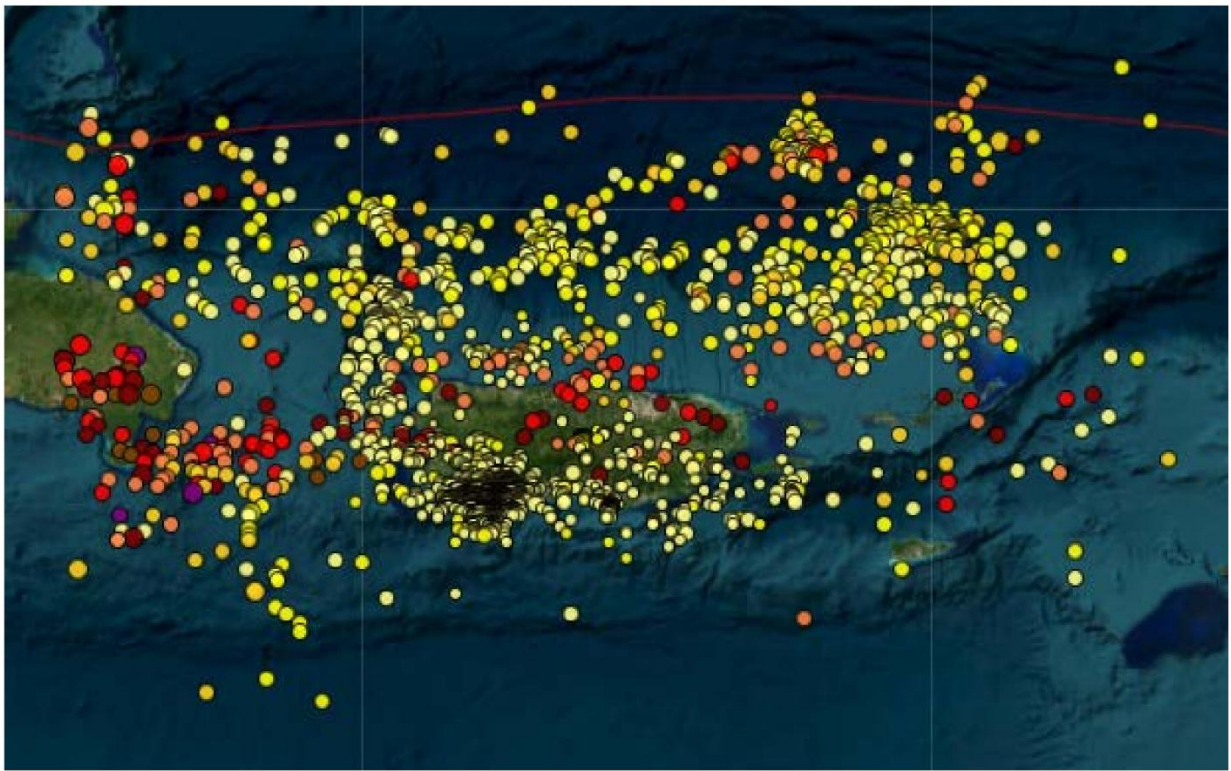
4.6.1.3 *Past Events (B1-d)*

Earthquakes occur naturally daily, and their impacts increase significantly with greater magnitude. High-magnitude events can be particularly destructive, causing extensive property damage, loss of life, and severe disruption to affected regions. Puerto Rico is located near several active seismic zones including the Puerto Rico Trench, the Mona Canyon, the Anegada Trough, the Muertos Trough, and the southern fault system placing the island at heightened risk for seismic events. Seismicity in the southeastern region of Puerto Rico is primarily associated with faults in the Virgin Islands and Anegada depressions. In the southwestern region, activity is influenced by the Punta Montalva fault (Roig Silva, 2010), an area that has experienced a notable increase in seismic activity in recent years (Weilert & Laó-Dávila, 2023).

Figure 13 is a screengrab sourced from a report published by the Puerto Rico Seismic Network (in Spanish). This report illustrates the epicenters of earthquakes recorded in the Puerto Rico and U.S. Virgin Islands region in 2024 (PRSN, 2025). The color scale represents the magnitude with warmer colors generally indicating stronger seismic events and cooler colors representing lower-magnitude earthquake.

⁸ Source: USGS, 2025

Figure 13. PRSN – 2024 Earthquakes Epicenter screengrab (PRSN, 2025)



Earthquake Chronology

Table 20 below shows the chronological list of the seismic activity in Puerto Rico for the period of 2012 to 2024 as reported by the PRSN (PRSN, n.d.).

Table 20. Puerto Rico Seismic Activity 2013-2024

Year	Description of seismic events
2024	The largest earthquake of 2024 occurred on May 14, 2024, at 8:30:11 p.m. (Puerto Rico local time). The magnitude 5.6 MI earthquake was located 94.3 km north-northwest of Aguadilla (PR) at a depth of 7 km. This moderate earthquake was widely felt throughout Puerto Rico, with a maximum intensity of V (Modified Mercalli Intensity Scale, MMI) in Aguadilla (PR). During 2024, aftershocks from the South-Southwest Puerto Rico seismic sequence continued. This sequence began on December 28, 2019, with a magnitude 4.7 MI earthquake. The main event of this sequence occurred on January 7, 2020, in the southern region of Puerto Rico, 12.7 km south of Guayanilla, with a magnitude of 6.4 Mw. This strong earthquake, at a depth of 7 km, had a maximum intensity of VIII in

Year	Description of seismic events
	Guánica, Puerto Rico, and caused major damage across the island. From the start of the South-Southwest Puerto Rico seismic sequence in 2019 through April 2024, 27,497 earthquakes associated with this sequence have been processed. More than 1,688 felt earthquakes and over 492 significant events with magnitudes greater than 3.5 have been recorded. Of these, 42 earthquakes had magnitudes greater than 4.5.
2023	The largest earthquake of 2023 occurred on December 9, 2023, at 10:27:22 a.m. (Puerto Rico local time). The magnitude 5.7 MI earthquake was located 192.28 km east-northeast of San Juan, PR, at a depth of 7 km. This moderate earthquake was widely felt throughout Puerto Rico and the Virgin Islands, with a maximum intensity of V (Modified Mercalli Intensity Scale, MMI) in St. Thomas (USVI). During 2023, aftershocks from South-Southwest Puerto Rico seismic sequence continued. This sequence began on December 28, 2019, with a magnitude 4.7 MI earthquake. The main event of this sequence occurred on January 7, 2020, in the southern region of Puerto Rico, 12.7 km south of Guayanilla, with a magnitude of 6.4 Mww. This strong earthquake, at a depth of 7 km, had a maximum intensity of VIII in Guánica, Puerto Rico, and caused major damage across the island.
2022	The seismic sequence in the South-Southwest region of Puerto Rico, which began on December 28, 2019, continues. From its onset until the March 2022 report by the Puerto Rico Seismic Network, a total of 19,436 earthquakes associated with this sequence had been recorded. In that report, 1,502 events were documented for 2022, of which 30 were reported as felt. The regions with the highest seismic activity during March 2022 were in the southern area of Puerto Rico.
2021	The largest earthquake of 2021 occurred on January 24, 2021, at 7:21:41 p.m. (Puerto Rico local time). The magnitude 5.4 MI earthquake was located 44.82 km southeast of Virgin Gorda, BVI, at a depth of 94 km. This moderate earthquake was widely felt throughout Puerto Rico and the Virgin Islands, with a maximum intensity of V (Modified Mercalli Intensity Scale, MMI) in Tortola, British Virgin Islands.
2020	The year 2020 was marked by significant seismic activity. An earthquake of magnitude 5.8 was recorded on January 6, 2020, followed by another of 6.4 on January 7, 2020, located 8 km from Indios, Puerto Rico. It is important to clarify that, starting from the 4.7 magnitude event recorded on December 28, 2019, up to October 22, 2020, approximately over 1,200 earthquakes of magnitude 2.0+ have been felt on the island. Tectonic activity in Puerto Rico is dominated by the convergence between the North American and Caribbean plates, with the island compressed between the two. To the north of Puerto Rico, the North American plate subducts beneath the Caribbean plate along the Puerto Rico Trench. To the south of the island, and south of the January 7 earthquake, the upper crust of the Caribbean plate subducts beneath Puerto Rico in the Muertos Trough. However, the January 6 earthquake and other recent events are occurring in the offshore deformation zone, connected by the

Year	Description of seismic events
	Punta Montalva fault on land and the Guayanilla Canyon offshore. Between December 28, 2019, and January 23, 2020, southern Puerto Rico recorded 90 seismic events of magnitude 4.0 or greater, including the 6.5 magnitude earthquake on January 7, 2020, according to the USGS. These seismic movements led state authorities to request a disaster declaration from the President of the United States. This Disaster Declaration was issued on January 16, 2020, under number DR-4473. The Municipality of Aguada was not included among those designated to receive Individual Assistance funds from FEMA.
2019	During 2019, the Puerto Rico Seismic Network (PRSN) located a total of 6,510 earthquakes in the Puerto Rico and Virgin Islands region (our seismic responsibility area, between latitudes 17°N–20°N and longitudes 63.5°W–69°W). Compared to 2018 (3,974 earthquakes), the detected and located seismicity in 2019 increased. The year 2019 ended with 2,536 more earthquakes than the previous year. In 2019, the month with the highest activity was December with 1,291 earthquakes, while August had the lowest seismicity with 303 earthquakes. The region with the highest recorded seismicity during 2019 was the Mona Canyon with 1,288 seismic events, followed by the southern region of Puerto Rico with 885 earthquakes. Earthquake depths ranged from 1 km to 191 km, and magnitudes varied from 0.34 Md to 6.0 Mw. Of the total earthquakes in 2019, 70 were reported as felt. On December 28, 2019, an active period of seismic activity began, with a 4.7 magnitude earthquake, followed several hours later by another 5.0 magnitude south of the island.
2018	During 2018, the Puerto Rico Seismic Network (PRSN) located a total of 3,974 earthquakes in the Puerto Rico and Virgin Islands region (our seismic responsibility area, between latitudes 17°N–20°N and longitudes 63.5°W–69°W). Compared to 2017 (3,129 earthquakes), the detected and located seismicity increased by 845 more earthquakes than the previous year. In 2018, the month with the highest activity was December with 549 earthquakes, while February had the lowest seismicity with 227 earthquakes. The region with the highest recorded seismicity during 2018 was the southern region of Puerto Rico with 412 seismic events, followed by the 19°N Fault Zone with 349 earthquakes. Earthquake depths ranged from 2 km to 185 km, and magnitudes varied from 0.63 Md to 4.67 Md. Of the total earthquakes in 2018, 29 were reported as felt within our area of responsibility.
2017	During 2017, the Puerto Rico Seismic Network (PRSN) located a total of 3,129 earthquakes in the Puerto Rico and Virgin Islands region (our seismic responsibility area, between latitudes 17°N–20°N and longitudes 63.5°W–69°W). Compared to 2016 (3,948 earthquakes), the detected and located seismicity decreased by 20%, which means 819 fewer earthquakes than the previous year. In 2017, the month with the highest activity was April with 518 earthquakes, while October had the lowest seismicity with 48 seismic events. The region with the highest recorded seismicity during 2017 was the Sombrero

Year	Description of seismic events
	Seismic Zone with 856 seismic events, followed by the Virgin Islands Platform with 327 earthquakes. Earthquake depths ranged from 1 km to 180 km, and magnitudes varied from 0.85 Md to 4.8 Mb. Of the total earthquakes in 2017, 24 were reported as felt within our area of responsibility.
2016	During 2016, the Puerto Rico Seismic Network (PRSN) located a total of 3,947 earthquakes in the Puerto Rico and Virgin Islands region (our seismic responsibility area, between latitudes 17°N–20°N and longitudes 63.5°W–69°W). Compared to 2015 (3,235 earthquakes), the detected and located seismicity increased by 22.0%, or 712 more earthquakes than the previous year. In 2016, the month with the highest activity was September with 566 earthquakes, while March had the lowest seismicity with 169 earthquakes. The region with the highest recorded seismicity during 2016 was the Sombrero Seismic Zone with 973 seismic events, followed by the Virgin Islands Platform with 497 earthquakes. Earthquake depths ranged from 1 km to 177 km, and magnitudes varied from 0.76 Md to 4.6 Ml. Of the total earthquakes in 2016, 28 were reported as felt within our area of responsibility.
2015	During 2015, the Puerto Rico Seismic Network (PRSN) located a total of 3,235 earthquakes in the Puerto Rico and Virgin Islands region (our seismic responsibility area, between latitudes 17°N–20°N and longitudes 63.5°W–69°W). Compared to 2014 (3,420 earthquakes), the detected and located seismicity decreased by 5.4%, or 185 fewer earthquakes than the previous year. In 2015, the month with the highest activity was July with 473 earthquakes, while April had the lowest seismicity with 157 earthquakes. The region with the highest recorded seismicity during 2015 was the Sombrero Seismic Zone with 588 seismic events, followed by the 19°N Fault Zone with 477 earthquakes. Earthquake depths ranged from 1 km to 211 km, and magnitudes varied from 0.80 Md to 4.80 Md (duration magnitude). Of the total earthquakes in 2015, 23 were reported as felt within the area of responsibility.
2014	During 2014, the Puerto Rico Seismic Network (PRSN) located a total of 3,420 earthquakes in the area of responsibility (AOR) known as the Puerto Rico and Virgin Islands Region (latitude 17.00° to 20.00°N and longitude 63.50° to 69.00°W). Compared to 2013 (2,293 earthquakes), the detected and located seismicity increased by 49%, which is 1,127 more earthquakes than the previous year. In this year, the month with the highest seismicity was January with 709 earthquakes, and the month with the lowest seismicity was November with 192 earthquakes. Of the total seismicity in 2014, 29 earthquakes (0.85%) were reported as felt, all located within our AOR. The magnitudes (Md) of the seismic events calculated for this year by PRSN ranged from 1.0 to 6.4, although for felt events they ranged from 2.53 Md to 6.4 Mwp. During 2014, depths varied between 1 km and 182 km, while for felt earthquakes they ranged from 6 km to 134 km. Earthquakes with depths of 0 to 25 km were the most frequent with 1,385 events, while those between 175 km and 200 km were the least frequent this year. The region with the highest recorded

Year	Description of seismic events
	seismicity during 2014 was the 19°N Fault Zone with 905 seismic events, followed by the Sombrero Seismic Zone with 483 earthquakes.
2013	During 2013, the Puerto Rico Seismic Network (PRSN) located a total of 2,293 earthquakes in the Puerto Rico and Virgin Islands region (latitude 17.00° to 20.00°N and longitude 63.50° to 69.00°W). Compared to 2012 (2,852 earthquakes), the detected and located seismicity decreased by 20%, which is 559 fewer earthquakes than the previous year. In this year, the month with the highest seismicity was September with 272 earthquakes, and the month with the lowest seismicity was February with 114 earthquakes. Of the total seismicity in 2013, 44 earthquakes (1.92%) were reported as felt, all located within the Puerto Rico and Virgin Islands region. The magnitudes of the seismic events calculated for this year by PRSN ranged from 1.0 to 5.12, although for felt events they ranged from 2.36 to 5.12. During 2013, depths varied between 1 km and 182 km, while for earthquakes they ranged from 4 km to 112 km. The region with the highest recorded seismicity during 2013 was the Sombrero Seismic Zone with 504 seismic events, followed by the Virgin Islands Platform with 246 earthquakes. Through its educational program, PRSN reached 14,099 people in Puerto Rico and the U.S. and British Virgin Islands during 2013.

2020 Seismic Sequence

In early January 2020, Puerto Rico experienced a significant seismic sequence that began with a series of foreshocks and culminated in a major earthquake on January 7. The main shock registered a magnitude of 6.4 Mw and struck along the island's southern coast, severely affecting the municipalities of Guayanilla, Ponce, and Yauco. This event was preceded by a magnitude 5.8 Mw earthquake on January 6, which had already caused widespread concern and notable structural damage (USGS, n.d.). The seismic activity was associated with the complex interaction between the Caribbean and North American tectonic plates, a region characterized by active subduction zones and fault systems. The resulting shaking was felt across the island, causing power outages, school closures, and the collapse of numerous structures, including residential and public buildings.

The aftermath of the earthquake resulted in extensive damage to homes and critical infrastructure, displacing thousands of residents and prompting a federal emergency declaration. The southern region experienced prolonged aftershocks—some exceeding magnitude 5.0, which continued for weeks, intensifying public concern and creating sustained disruption. This event underscored Puerto Rico's heightened

vulnerability to seismic hazards and highlighted the importance of preparedness measures and resilient construction practices. The incident received a Presidential Disaster Declaration under the Stafford Act (DR-4473-PR) (FEMA, n.d.). Although the Municipality of Aguada was not designated for Public Assistance under this declaration, it was included for Individual Assistance, reflecting the impacts experienced by residents following the event. While the most severe earthquake damage occurred in the southern region of Puerto Rico, the event underscored the vulnerability of all municipalities to seismic hazards and the importance of preparedness measures, resilient construction practices, and emergency planning. Aguada recognizes that Puerto Rico's location along active tectonic boundaries places all jurisdictions at risk of seismic events capable of causing significant damage and disruption to daily life.

According to the Puerto Rico Seismic Network (PRSN), from the onset of the South-Southwest Puerto Rico seismic sequence in 2019 through April 2024, a total of 27,497 earthquakes associated with this sequence were recorded and processed. Of these events, more than 1,688 were reported as felt, and over 492 registered magnitudes greater than 3.5. Additionally, 42 earthquakes reached magnitudes exceeding 4.5.

4.6.1.4 Future Event Probabilities (B1-e)

Unlike atmospheric hazards, earthquakes cannot be predicted with current scientific capabilities. However, advances in seismology allow for the development of probabilistic forecasts. Historical records indicate that Puerto Rico has experienced four major destructive earthquakes since 1670—specifically in 1670, 1787, 1867, and 1918. This sequence suggests a recurrence interval ranging from 51 to 117 years, with an average interval of approximately 83 years for significant events. It is important to note, however, that each of these earthquakes originated on different fault systems; therefore, this record alone cannot be used to establish a precise recurrence rate.

For more comprehensive analyses, geologic maps of specific zones are examined to identify active faults and other relevant structural features. These datasets are then correlated with historical earthquake intensity distributions, seismic attenuation models, and statistical records. This integrated approach produces maps of seismically active areas that delineate regions with varying potential for strong earthquake activity. Identifying these high-risk zones is essential for informed land-use planning and effective emergency preparedness.

In the case of Puerto Rico, the PRSN cites a probabilistic seismic hazard study

conducted in 1987 by Dr. William McCann, which estimated a 33–50% probability of a strong earthquake (Intensity VII or higher on the Modified Mercalli Scale) occurring in various parts of the island within a 50-year period (PRSN, 2025).

Further research conducted by the U.S. Geological Survey in 2003 identified an area west–southwest of Puerto Rico as the region most likely to experience strong earthquakes on the island. This probabilistic analysis does not account for secondary hazards such as tsunamis, liquefaction, or seismic wave amplification, which predominantly affect low-lying coastal areas and high-elevation zones susceptible to landslides.

4.6.2 Risk Analysis (B2-a, B2-b)

4.6.2.1 *Estimated Losses*

Municipal Exposure

Table 21 presents the estimated exposure of the Municipality of Aguada to earthquake hazards based on FEMA’s National Risk Index (NRI) methodology. Exposure represents the total value of assets and population potentially affected by a future earthquake event within the municipality.

It is important to note that, while assigning an exact monetary value to human life is inherently complex, FEMA converts population exposure into an economic estimate using a population equivalence methodology based on the Value of Statistical Life (VSL). Under this approach, each fatality—or the equivalent of ten injuries—is assigned an economic loss value of \$13.7 million, reflecting FEMA’s inflation-adjusted VSL estimate. All historical loss figures are subsequently adjusted to December 2024 dollars to account for inflation.

According to the HAZUS 6.1 and FEMA National Risk Index datasets, Aguada has an estimated total earthquake exposure of approximately \$447.3 billion. This estimate includes approximately \$4.96 billion in building exposure and \$442.38 billion in population-equivalent exposure. The municipality encompasses approximately 31.26 square miles of potentially affected area and a population exposure of 38,136 residents. These results demonstrate the significant exposure of the municipality’s population, buildings, and critical infrastructure to future seismic events.

Table 21 summarizes the municipality's earthquake exposure as reported in FEMA's National Risk Index.

Table 21. Exposure to Earthquake Hazard

Exposure - Impacted Area (sq mi)	Exposure - Building Value	Exposure - Population	Exposure - Population Equivalence	Exposure - Total
31.26	\$4,957,801,000	38,136	\$442,377,600,000	\$447,335,401,000

Source FEMA's NRI

Annual Expected Loss

The Federal Emergency Management Agency's HAZUS Earthquake Analysis provides estimates of Annualized Earthquake Losses defined as the long-term average annual economic impact of earthquakes on the general building stock within a given geographic area as well as annualized estimates of population loss.

The Annualized Earthquake Loss is calculated using the Riemann Sums Method, which averages the annual losses associated with multiple return periods and then multiplies each average loss by its corresponding differential probability to produce a single loss estimate for each Census tract. (FEMA, National Risk Index Data - Technical Documentation, 2025)

The expected annual loss for each census tract or jurisdiction represents the average yearly economic impact, expressed in dollars, anticipated from natural hazard events. According to the HAZUS 6.1 and FEMA National Risk Index datasets, the Municipality of Aguada has an estimated Annual Expected Loss of approximately \$9.3 million from earthquake hazards, including \$5.1 million in building losses and \$4.1 million in population-equivalent losses, as summarized in Table 22. These losses reflect the long-term economic risk that earthquakes pose to the municipality.

Table 22. Expected Annual Loss to Earthquake

Expected Annual Loss - Building Value	Expected Annual Loss - Population	Expected Annual Loss - Population Equivalence	Expected Annual Loss - Total
\$5,126,799	0.36	\$4,128,078	\$9,254,877

Source FEMA's NRI

4.6.2.2 *Lifelines and Critical Infrastructure*

Earthquakes can affect a community's lifelines in the following ways:

- **Safety and Security** – An earthquake can cause the structural failure of critical facilities such as police stations and fire stations, generate increased demand for search-and-rescue operations, and result in population displacement requiring emergency sheltering. Such conditions may also create challenges in maintaining public order and ensuring community security.
- **Food, Hydration, and Shelter** – A seismic event can cause damage to water treatment plants and distribution systems, resulting in contamination or loss of potable water. Disruptions to transportation routes and storage facilities may also interrupt food supply chains. Widespread structural damage can increase the demand for temporary shelters. Additionally, the loss of refrigeration capacity may lead to significant spoilage of perishable goods.
- **Health and Medicine** – Hospitals and clinics may experience structural damage or a reduction in operational capacity during an earthquake. A surge in injuries requiring emergency medical attention can overwhelm existing healthcare facilities. Disruptions to pharmaceutical supply chains and medical logistics may also occur. Additionally, compromised sanitation conditions in emergency shelters can elevate the risk of disease outbreaks.
- **Energy** – Damage to power plants, substations, and transmission lines can result in widespread power outages. Ruptures in gas lines may create fire and explosion hazards. Interruptions in the fuel supply chain can also impede the operation of generators and emergency response vehicles.
- **Communications** – Damage to cell towers, fiber-optic cables, and communication hubs can result in significant loss of connectivity. Emergency call surges may overload telecommunications networks, further degrading service availability. These disruptions can impair coordination among emergency response agencies and hinder the timely dissemination of critical information.
- **Transportation** – Collapse or severe damage to roads, bridges, and tunnels can significantly restrict mobility. Airports and seaports may become inoperable due to damage to runways or docks. Rail systems, including the Tren Urbano, may also be disrupted because of track deformation or landslides.
- **Hazardous Materials** – An earthquake may cause spills from industrial facilities, chemical plants, or storage tanks, increasing the risk of environmental contamination affecting air, soil, and water resources. Additionally, damage to sites containing hazardous materials may result in fires or explosions.

- **Water Systems** – Breakage of water mains and sewer lines can result in localized flooding and contamination. Such damage may also reduce firefighting capacity due to diminished water pressure and lead to long-term disruptions in wastewater collection and sanitation services.

Maps 16 and 17 show the identified critical infrastructure locations in relation to the spectral acceleration areas shown in Section 4.6.1.

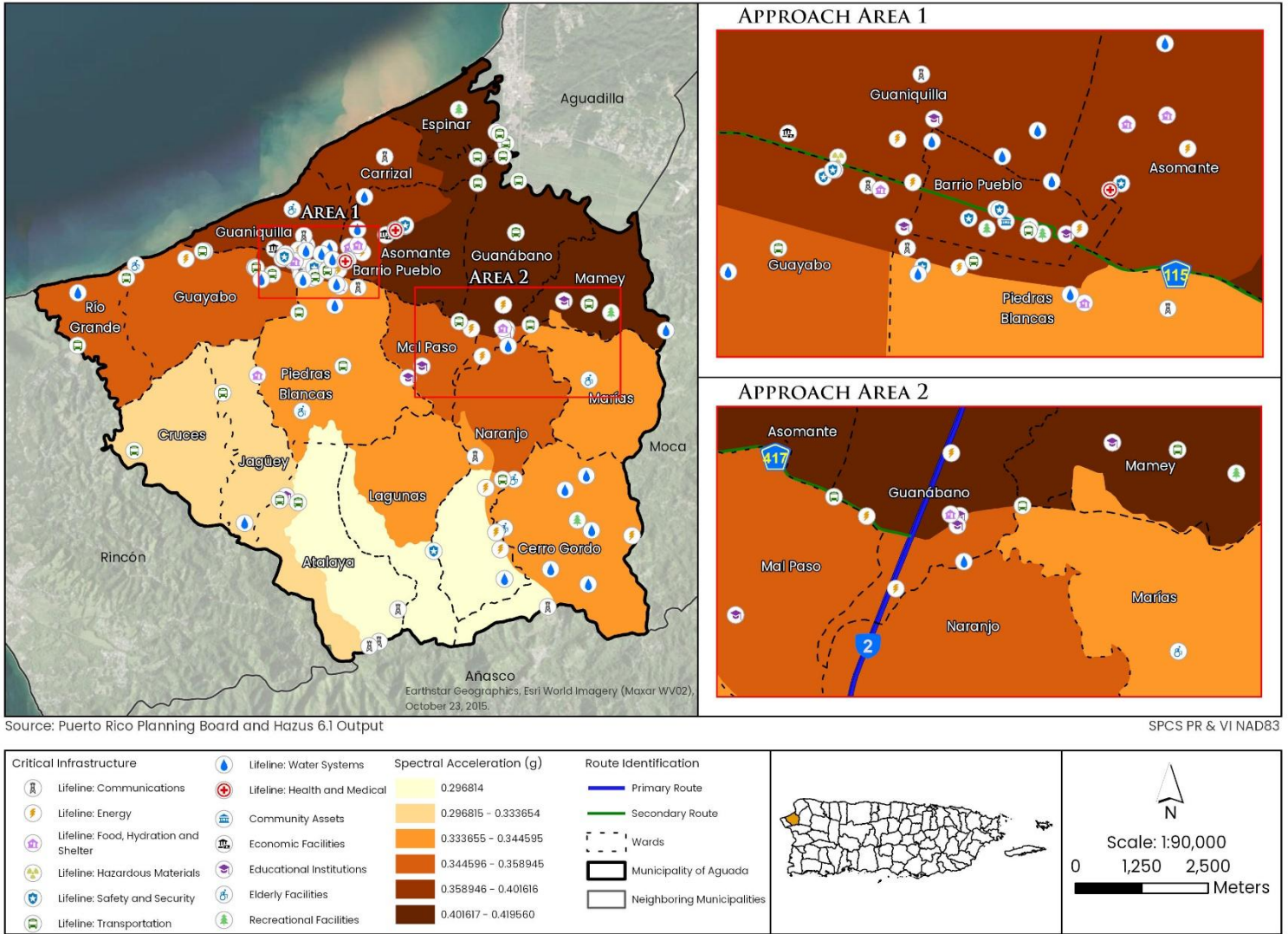
These maps show that many critical facilities are located in areas of high spectral acceleration, particularly within and around Barrio Pueblo, Asomante, Guaniquilla, Guanábano, Carrizal, and Mamey. The highest concentration of facilities is located near the municipal urban center, where multiple lifelines overlap, including health and medical facilities, public safety facilities, educational institutions, transportation assets, communications infrastructure, and water system facilities.

Maps 16 and 17 also show that several critical facilities associated with the Health and Medical, Safety and Security, Food, Hydration and Shelter, Transportation, Communications, and Water Systems lifelines are located within the areas of highest spectral acceleration. The concentration of critical infrastructure within these areas highlights the potential for earthquakes to affect multiple community lifelines simultaneously and emphasizes the importance of preparedness, continuity of operations planning, and mitigation measures aimed at reducing risks to essential public services.

In the case of Aguada, there is no significant difference between the areas covered by the highest spectral acceleration values in the 1.0-second and 0.3-second scenarios, as both analyses identify the northern and urbanized portions of the municipality as the areas with the greatest concentration of exposed critical facilities.

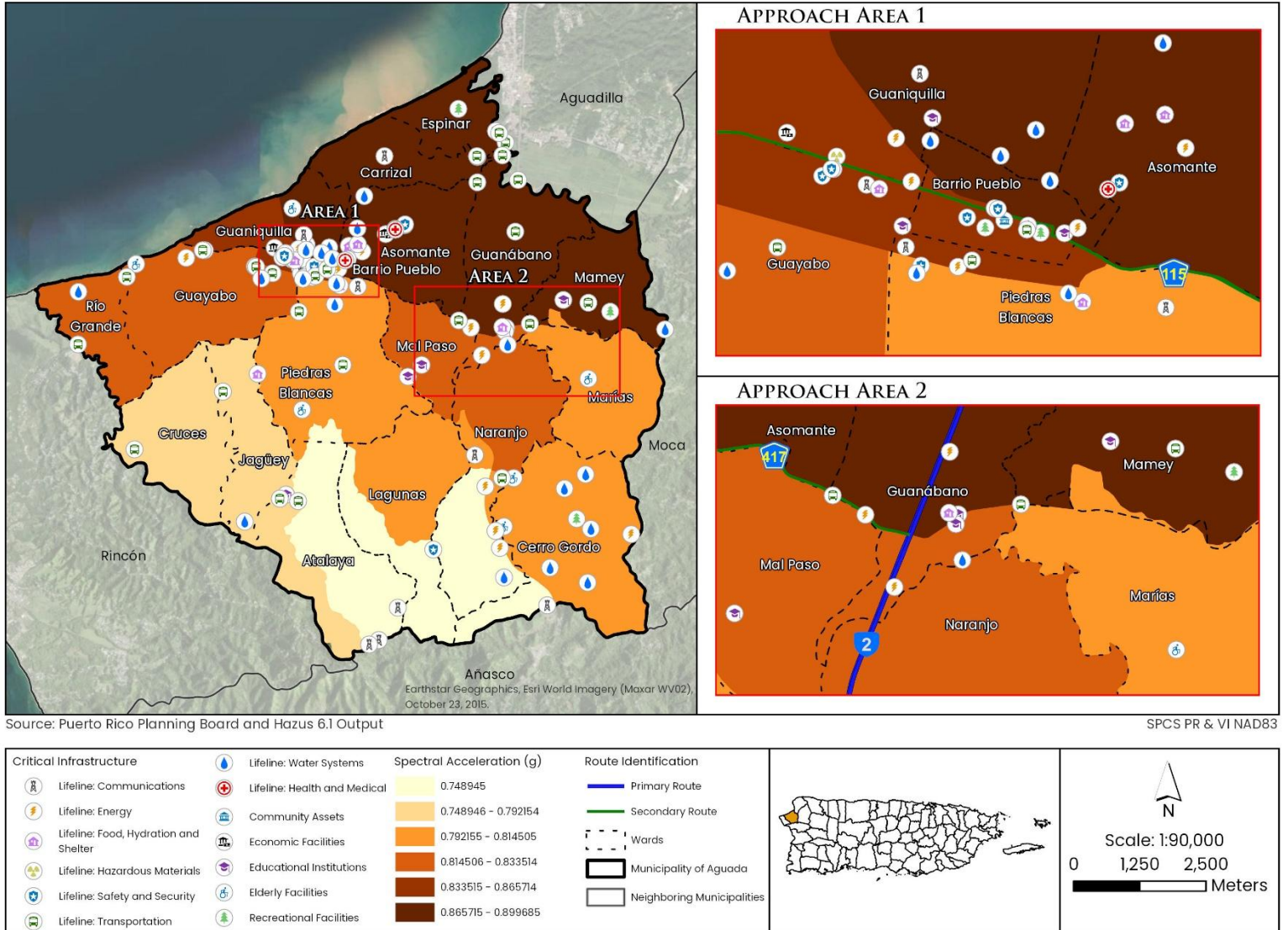
Map 16. Earthquake: Critical Facilities Exposure to Spectral Acceleration at 1.0 sec (g)

EARTHQUAKE: CRITICAL FACILITIES EXPOSURE TO SPECTRAL ACCELERATION AT 1.0 SEC (G)



Map 17. Earthquake: Critical Facilities Exposure in Spectral Acceleration at 0.3 sec (g)

EARTHQUAKE: CRITICAL FACILITIES EXPOSURE TO SPECTRAL ACCELERATION AT 0.3 SEC (G)



4.6.2.3 *Social Vulnerabilities*

Social vulnerability to earthquakes in Puerto Rico is shaped by high levels of poverty, aging infrastructure, and limited access to essential resources, all of which disproportionately affect the ability of communities to withstand and recover from seismic events. Many residents face compounding disadvantages—such as disability, low educational attainment, and limited vehicle access—that reduce their capacity to evacuate, access information, or secure aid after a damaging earthquake. Research on disaster governance also shows that systemic governmental neglect and energy insecurity intensify the impacts of disasters, leaving communities with fewer resilience mechanisms in the aftermath of earthquakes.

Puerto Rico’s disaster research literature identifies long-standing structural inequities that heighten vulnerability, including political and economic marginalization that limit long-term recovery and exacerbate risk accumulation across hazard types. Federal assessments further find that many census tracts exhibit high social vulnerability scores (US Census Bureau, 2024), (US Census Bureau, 2025), meaning that an earthquake’s impacts are likely to intersect with broader socio-economic fragility. Overall, these combined factors demonstrate that earthquakes in Puerto Rico pose not only a physical hazard but also a deep social challenge tied to historical, economic, and infrastructural conditions that shape uneven disaster outcomes. For more details about Social Vulnerabilities see section 3.4,

Notwithstanding the classification of the municipal territory into areas of spectral acceleration in section 4.6.1 This version of the LHMP will be more conservative than the previous version and will consider all of the population of Aguada equally vulnerable to the natural hazard of earthquake.

Maps 18 and 19 show the municipality’s population exposure to an earthquake by ward for spectral acceleration events of 1.0 sec. (g) and 0.3 sec. (g). The highest levels of population exposure are concentrated within the northern portion of the municipality, particularly in the wards of Asomante, Carrizal, Espinar, Guanábano, Guaniquilla, Barrio Pueblo, and Mamey, where the highest spectral acceleration values are present. Moderate levels of exposure are observed in portions of Guayabo, Grande River from Añasco, Mal Paso, Naranjo, and Marías, while the lowest exposure levels are generally located in the southern wards of Atalaya, Cruces, and Lagunas.

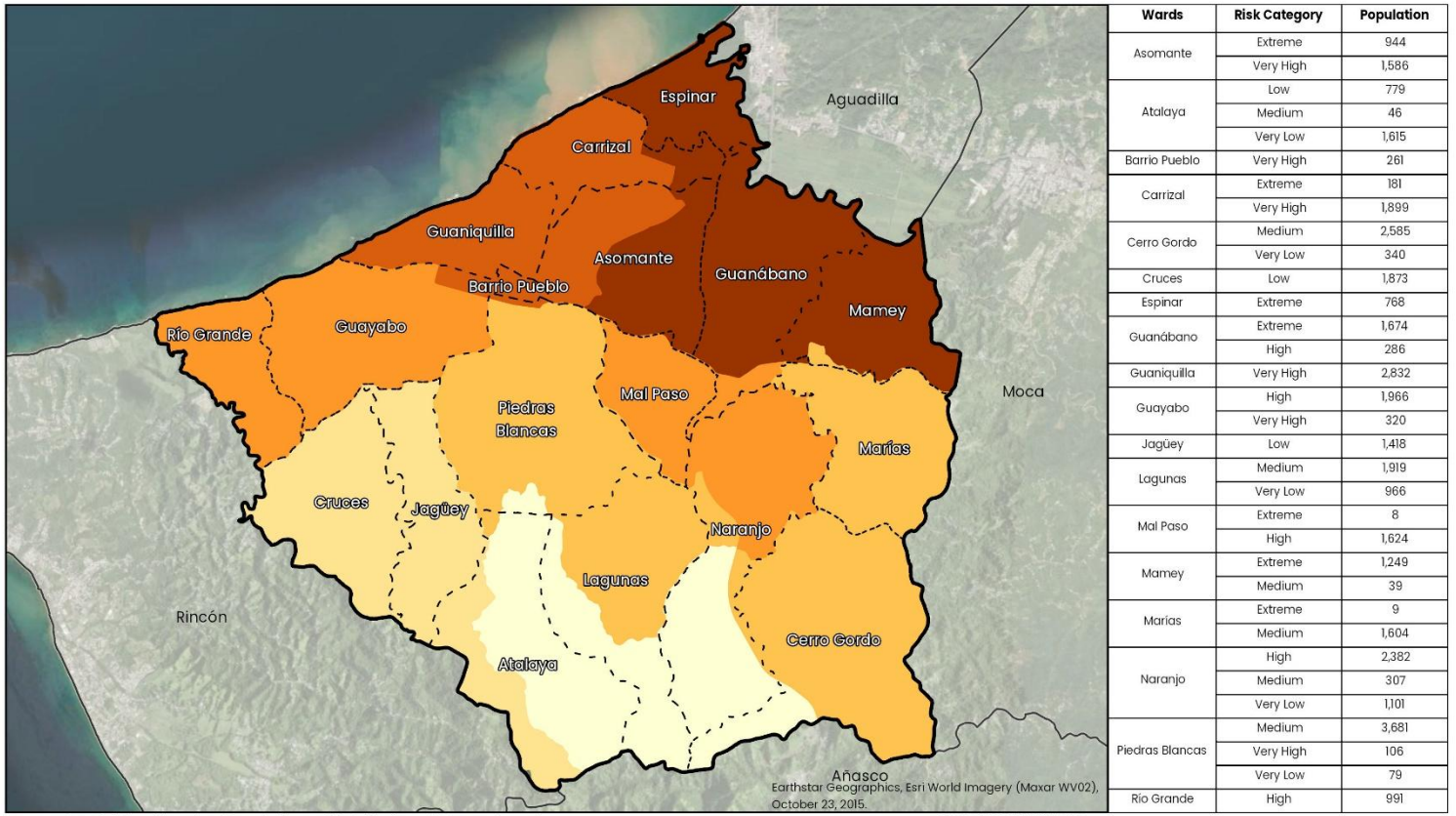
The maps indicate that a substantial portion of Aguada’s population resides within areas classified as High, Very High, or Extreme spectral acceleration zones. These

results highlight the potential for future earthquakes to affect a significant portion of the municipality's population and underscore the importance of mitigation measures, emergency preparedness, and public education efforts aimed at reducing seismic risk.

Similar exposure patterns are observed in both the 1.0-second and 0.3-second scenarios, indicating that the northern and more urbanized portions of Aguada remain the areas with the greatest concentration of population exposed to earthquake hazards

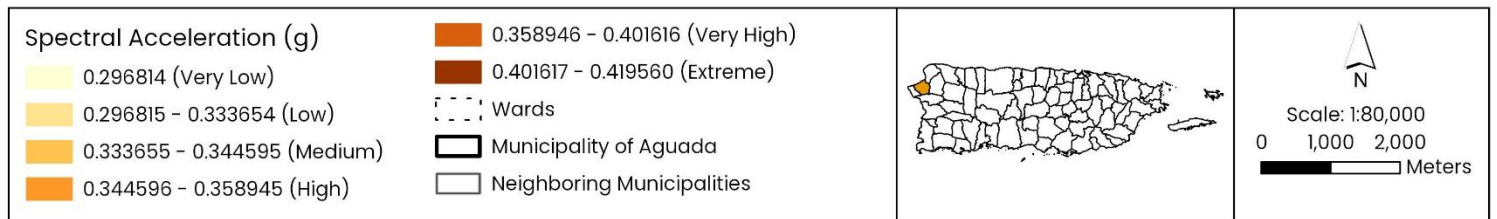
Map 18. Earthquake: Population Exposed to Spectral Acceleration at 1.0 sec(g)

EARTHQUAKE: POPULATION EXPOSURE TO SPECTRAL ACCELERATION AT 1.0 SEC (G)



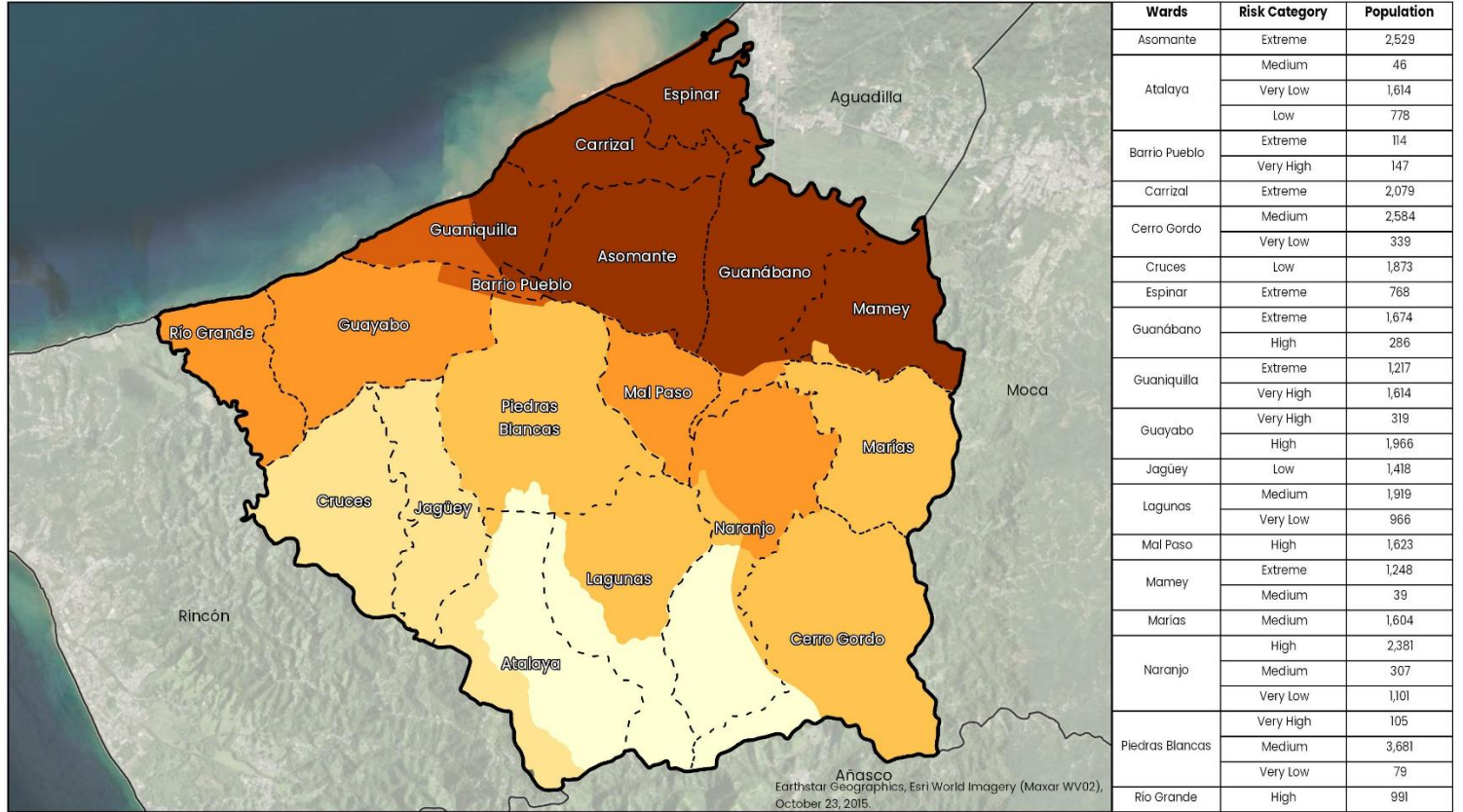
Source: Puerto Rico Planning Board, Hazus 6.1 Output and Census Tract

SPCS PR & VI NAD83



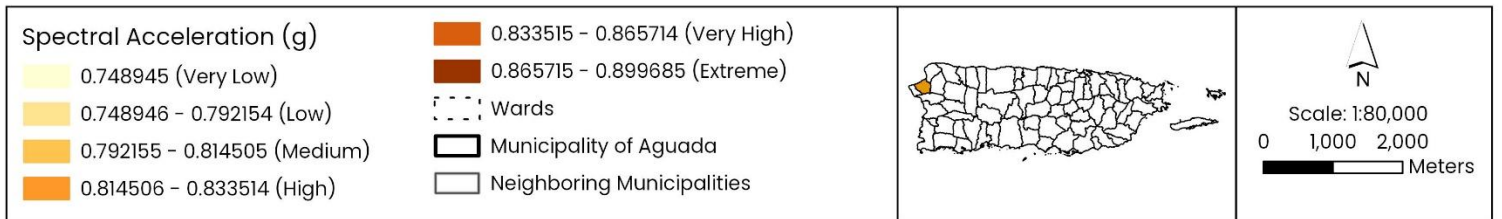
Map 19. Earthquake: Population Exposed to Spectral Acceleration at 0.3 sec (g)

EARTHQUAKE: POPULATION EXPOSURE TO SPECTRAL ACCELERATION AT 0.3 SEC (G)



Source: Puerto Rico Planning Board, Hazus 6.1 Output and Census Tract

SPCS PR & VI NAD83



4.6.2.4 *Natural and Cultural Resources*

Earthquakes can produce a wide range of impacts on natural and cultural resources:

- **Landslides and Soil Instability:** Seismic activity can trigger landslides, rockfalls, and soil liquefaction, altering natural landforms and damaging ecological habitats.
- **Water Quality and Hydrology:** Ground shaking may modify river pathways, impair aquifers, and increase sedimentation in water bodies, which can degrade water quality and disrupt aquatic ecosystems.
- **Vegetation and Wildlife:** Ground deformation and related secondary hazards such as flooding or fires can lead to habitat loss, fragmentation, and adverse effects on biodiversity.
- **Coastal and Marine Environments:** Submarine earthquakes may generate tsunamis, resulting in coastal erosion, coral reef degradation, and the deterioration of marine and estuarine ecosystems.

While the following damage can happen to Cultural Resources:

- **Seismic forces** can cause significant structural damage or the complete collapse of heritage structures, archaeological sites, and monuments.
- **Museums and Archives:** Earthquakes may lead to the loss, damage, or deterioration of artifacts, archival materials, and collections due to structural failures or insufficient seismic protection.
- **Community Identity and Tourism:** Damage to culturally important sites can undermine community identity and reduce tourism activity, thereby affecting local economic stability.

In the case of Aguada, the historic urban center in Barrio Pueblo is situated within an area characterized by high to very high spectral acceleration values. As a result, future earthquake events may affect historic buildings, public facilities, community landmarks, and other cultural resources concentrated within the municipality's traditional urban core. These resources include the Parroquia San Francisco de Asís, the historic town center, and the Ermita de Espinar in Barrio Espinar. The Ermita de Espinar is particularly significant as one of the oldest religious sites in Puerto Rico, with origins dating to the early sixteenth century. Damage to these resources could result in the loss of irreplaceable cultural and historic assets, adversely affecting the municipality's architectural heritage, cultural identity, and tourism resources.

4.6.2.5 *Future Conditions (E1-a)*

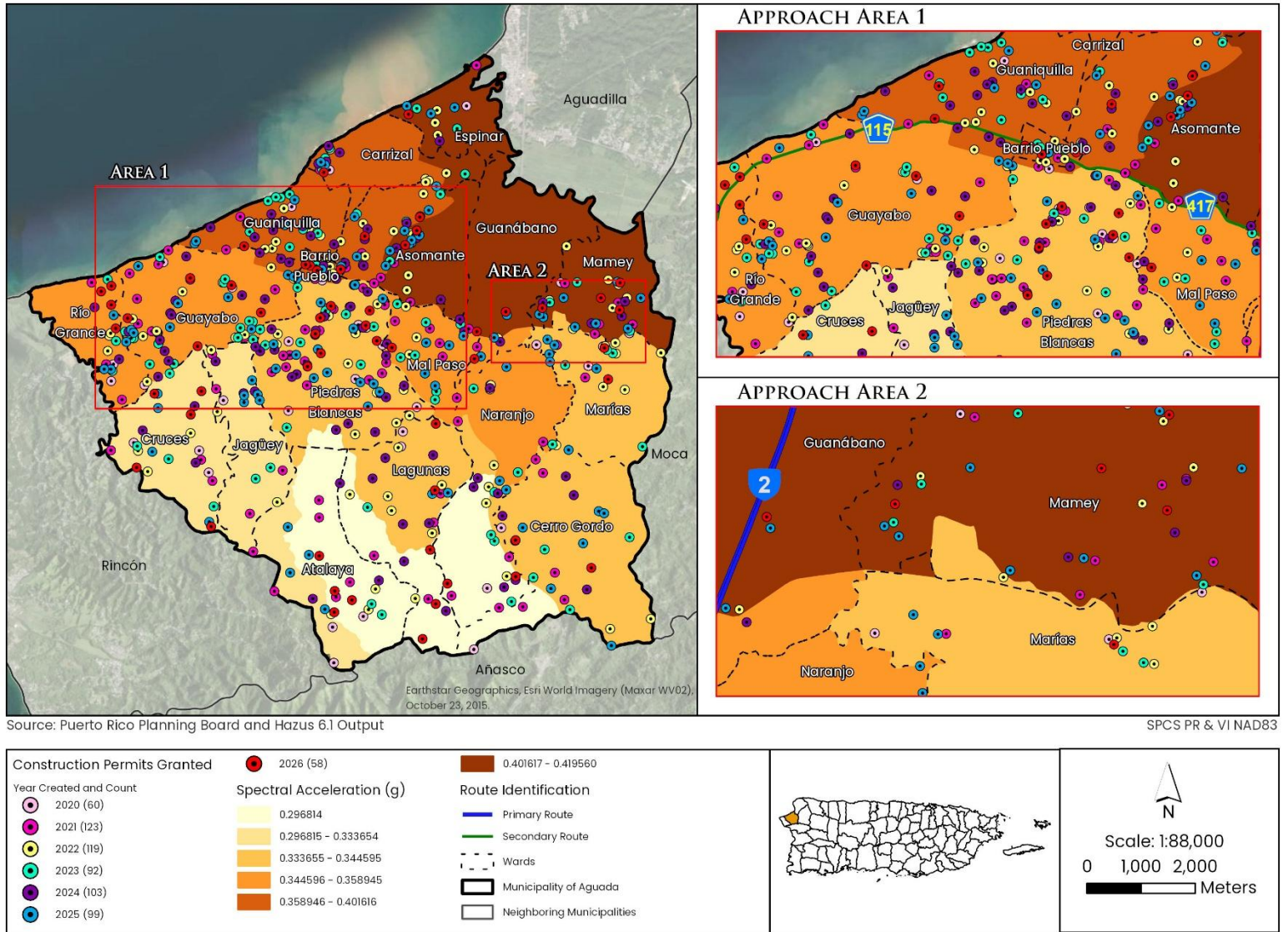
Future development within Aguada is expected to continue primarily within the municipality's northern and central wards, where much of the recent development activity has occurred. Map 20 and 21 indicate that a substantial portion of development completed between 2020 and 2026 is located within areas characterized by high to very high spectral acceleration values under both the 1.0 sec (g) and 0.3 sec (g) earthquake scenarios.

Section 3.6 above discussed the number of constructions permits issued in the Municipality. Map 20 and 21 shows that recent development is concentrated in the wards of Barrio Pueblo, Asomante, Guaniquilla, Carrizal, Guanábano, and Mamey, many of which correspond to areas expected to experience higher levels of ground shaking during future earthquake events. As development continues within these areas, additional residential, commercial, institutional, and infrastructure assets may become exposed to seismic hazards.

The similar exposure patterns observed in both spectral acceleration scenarios suggest that future growth may continue to occur in areas with elevated earthquake risk. Consequently, continued compliance with seismic design standards, land use planning practices, building code requirements, and hazard mitigation measures will be essential to reducing future earthquake-related losses and enhancing community resilience.

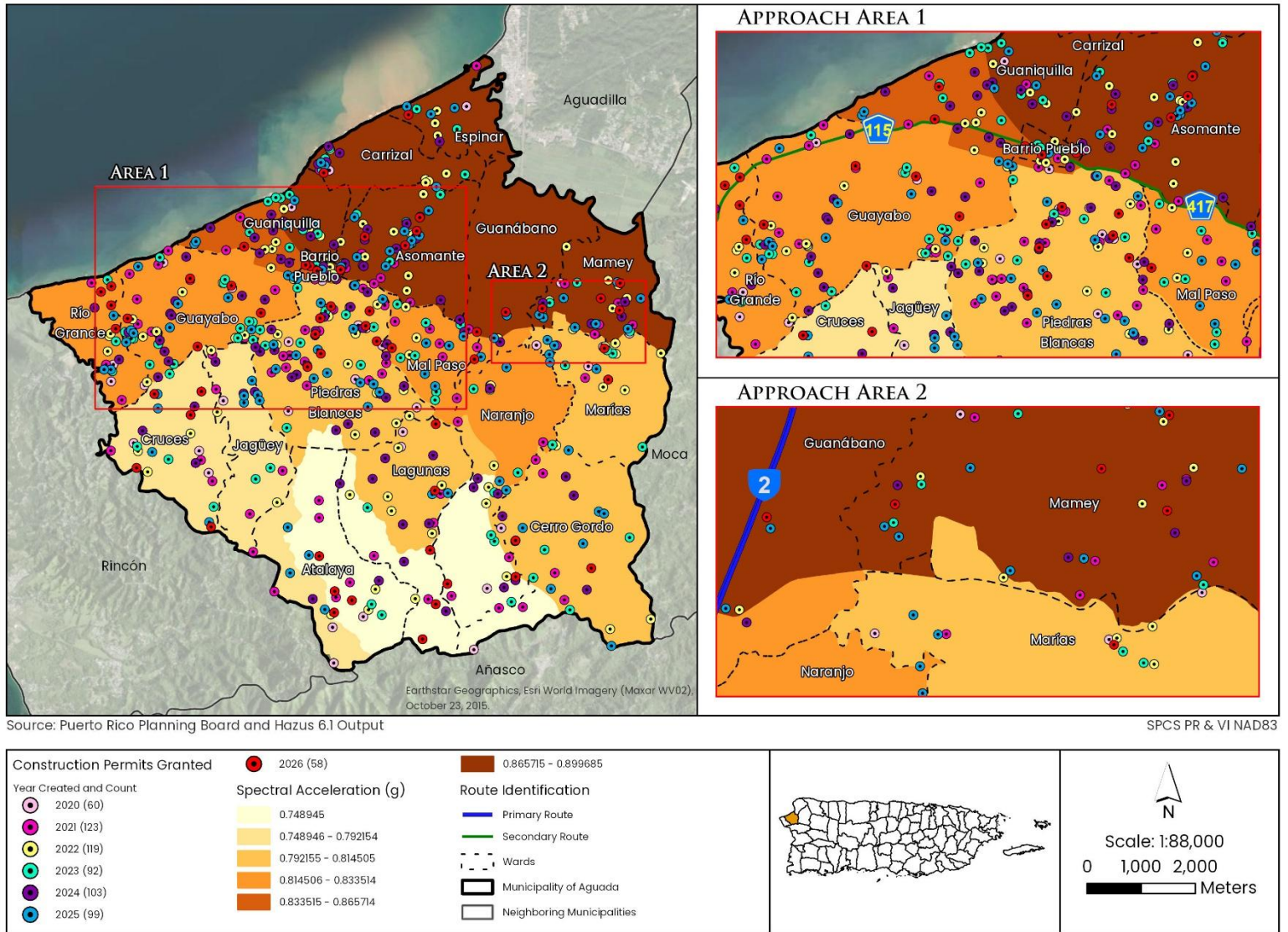
Map 20. Earthquake: Recent Development Exposure to Spectral Acceleration at 1.0 sec (g)

EARTHQUAKE: RECENT DEVELOPMENT EXPOSURE TO SPECTRAL ACCELERATION AT 1.0 SEC (G)



Map 21. Earthquake: Recent Development Exposure to Spectral Acceleration at 0.3 sec (g)

EARTHQUAKE: RECENT DEVELOPMENT EXPOSURE TO SPECTRAL ACCELERATION AT 0.3 SEC (G)



4.7 Landslides

4.7.1 Description (B1-a)

Landslides are a natural geomorphological process characterized by the downslope movement of soil, rock, or debris due to terrain instability. These events occur when environmental conditions align such that gravitational forces acting on surface materials exceed their natural resistance. The term landslide encompasses multiple types of ground displacement including rockfalls, slope failures, and debris flows, all of which pose significant risks to life and property. Such movements can obstruct transportation routes and carry with them vegetation, homes, bridges, vehicles, and other infrastructure, causing extensive disruption and damage (FEMA, 1997).

Prolonged and intense rainfall associated with meteorological systems such as tropical waves, troughs, and tropical cyclones is one of the primary triggers of landslide events. Additionally, population growth and the expansion of informal construction increase the municipality's exposure to landslide hazards. Potable water supply and wastewater systems including sanitary pipes, septic tanks, and storm sewers whether properly authorized or informally installed, can further exacerbate slope instability. The likelihood of landslides rises significantly when these systems leak or are inadequately sited or constructed (USGS, n.d.).

Multiple factors contribute to the development of landslides, including soil type, terrain slope, degree of soil saturation, erosion processes, the presence of depressions or subsurface voids, human activities, and seismic events. The Building Performance Assessment Report (BPAR) prepared after Hurricane Georges warns that "landslides will become a major problem in the future as more houses are built and more development occurs in areas susceptible to these risks." This observation underscores the increasing vulnerability associated with continued development in high-risk zones (FEMA, 1997).

Many landslides in Puerto Rico fall into a specific subtype known as debris flows. These events typically occur in mountainous areas with steep slopes during periods of intense rainfall. As rainwater infiltrates the ground, the soil becomes saturated and the underlying subsurface layer loses its cohesion. This loss of stability causes the material to detach often at the interface where the subsurface meets the bedrock resulting in a rapid downslope flow of soil, rock, and water.

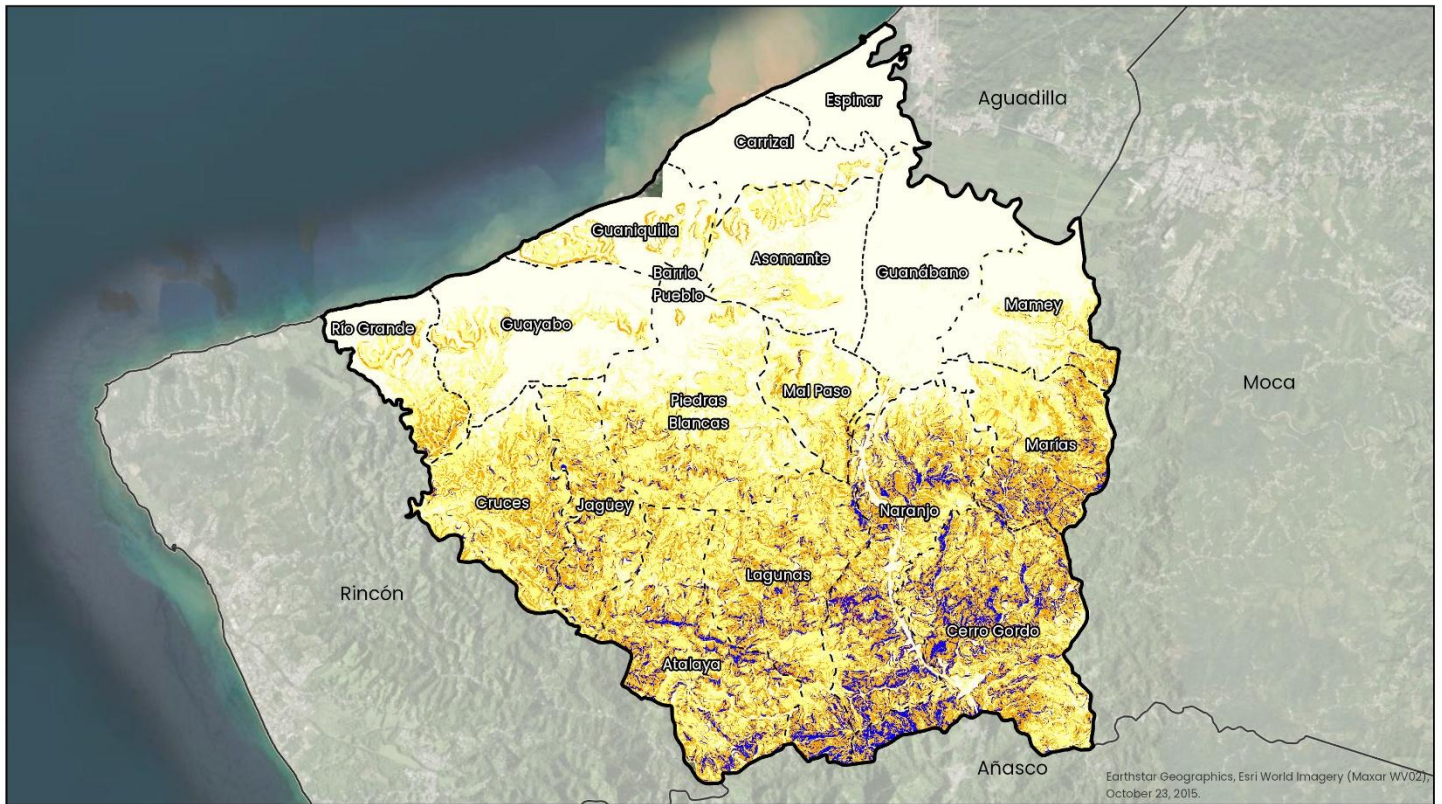
There are many types of landslides; however, those specifically linked to water-saturated soils include the following (PREMB, 2021):

- Slow Landslide: A gradual and sustained downslope movement of soil or rock. These events are often identifiable by displaced tree trunks, distorted or twisted fences and retaining walls, and leaning posts or structures.
- Debris Flow: A rapid mass movement in which loose soil, rocks, and organic material combine with infiltrated water and air to form a dense, viscous flow that travels swiftly down a hillside.
- Debris Avalanche: An extremely rapid or very fast-moving form of debris flow, characterized by high velocity and significant destructive potential.
- Mudflow: A fast-moving mass composed of water-saturated material containing at least 50 percent sand, silt, and clay particles.

4.7.1.1 Affected Area (B1-b)

According to landslide susceptibility data obtained from the United States Geological Survey (USGS), the Municipality of Aguada exhibits a distinct spatial pattern of landslide hazard, with susceptibility generally increasing from the northern coastal areas toward the more rugged terrain of the central and southern portions of the municipality. Areas of low susceptibility are predominantly located in the northern sectors, while moderate, high, and very high susceptibility zones are concentrated in areas characterized by steeper slopes and more complex topography. These conditions increase the potential for slope failures, particularly during periods of intense or prolonged rainfall. Identifying the distribution of landslide susceptibility throughout the municipality is essential for informing hazard mitigation strategies, land use planning, infrastructure protection, and emergency management efforts.

LANDSLIDE SUSCEPTIBILITY



4.7.1.2 Risk Magnitude (B1-c)

Landslides typically occur in steep, mountainous areas during periods of intense or prolonged rainfall. As water infiltrates the ground, the soil becomes saturated, weakening natural drainage systems and reducing the structural capacity of the terrain, which can ultimately lead to slope failure. Certain areas are inherently more susceptible to landslides than others, particularly those with greater slope gradients. Vegetation plays a critical role in maintaining soil cohesion and reducing surface erosion; therefore, slopes lacking vegetation are generally more prone to instability.

Slope stability is influenced by several factors, including elevation, steepness, vegetative cover, and underlying geology. In general, increases in slope height and inclination correlate with a greater likelihood of terrain instability. Below are key factors that contribute to the occurrence of landslides:

- The base of inclined slopes
- Areas near small depressions where drainage converges
- The lower portion of slopes is composed of fill - material
- The base or crest of a very steep slope
- Locations with a history of previous landslides
- Hillsides that have been developed and where septic systems are present
- Steep slopes underlain by clay-rich soils
- Hills or slopes with inclinations greater than 12 degrees and elevations exceeding 300 meters

The hazard categories are derived from the USGS classification index, which evaluates slope and soil characteristics as defined by the agency. The following table outlines these categories—low, moderate, high, and very high—and describes the corresponding levels of hazard.

Table 23. Landslide Risk Categories

Category	Description
Low	Areas with minimal slopes and stable soil; landslides are unlikely except under extreme conditions.
Moderate	Areas with some susceptibility; landslides may occur during prolonged or intense rainfall.
High	Areas with significant susceptibility; landslides are likely during heavy rain or seismic activity.
Very High	Areas extremely prone to landslides; frequent events during storms or

Category	Description
	earthquakes.

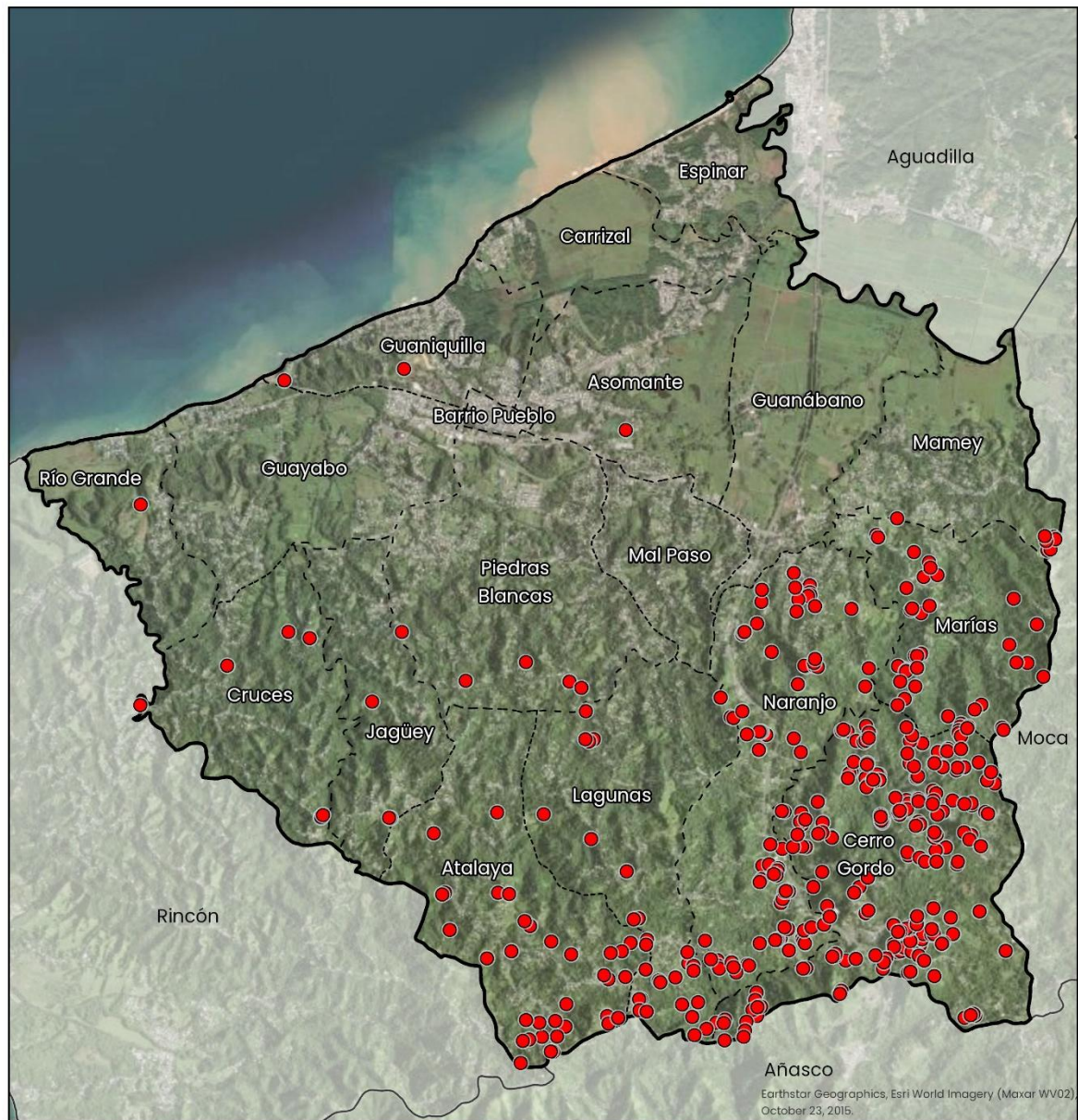
4.7.1.3 *Past Events*

As noted earlier, landslides are frequently associated with heavy rainfall events. Map 23 illustrates the landslides reported following Hurricane María in 2017, which generally correspond to the areas identified as having the greatest landslide susceptibility. The highest concentration of reported landslides occurred in the southern and southeastern portions of the municipality, particularly within the wards of Marías, Naranjo, Lagunas, Atalaya, and Mamey, where steeper terrain and mountainous conditions are present.

In contrast, relatively few landslides were reported within the more urbanized and coastal wards of Barrio Pueblo, Guaniquilla, Carrizal, Espinar, Grande River from Añasco, and portions of Guayabo. The spatial distribution of landslides following Hurricane María demonstrates the strong relationship between slope conditions, intense rainfall, and landslide occurrence, highlighting the increased vulnerability of the municipality's upland areas to future rainfall-induced slope failures.

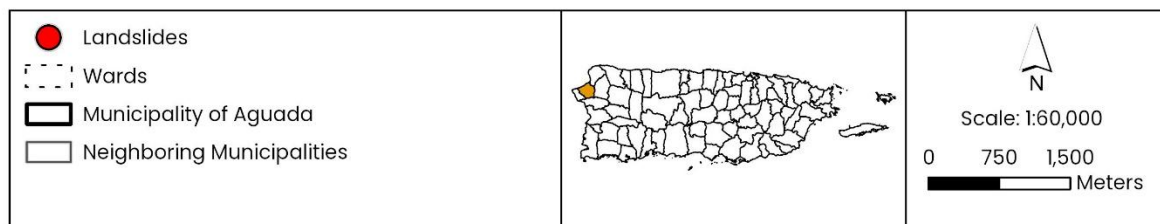
Map 23. Landslides reported in the aftermath of Hurricane María

LANDSLIDES REPORTED IN THE AFTERMATH OF HURRICANE MARÍA



Source: Puerto Rico Planning Board and United States Geological Service

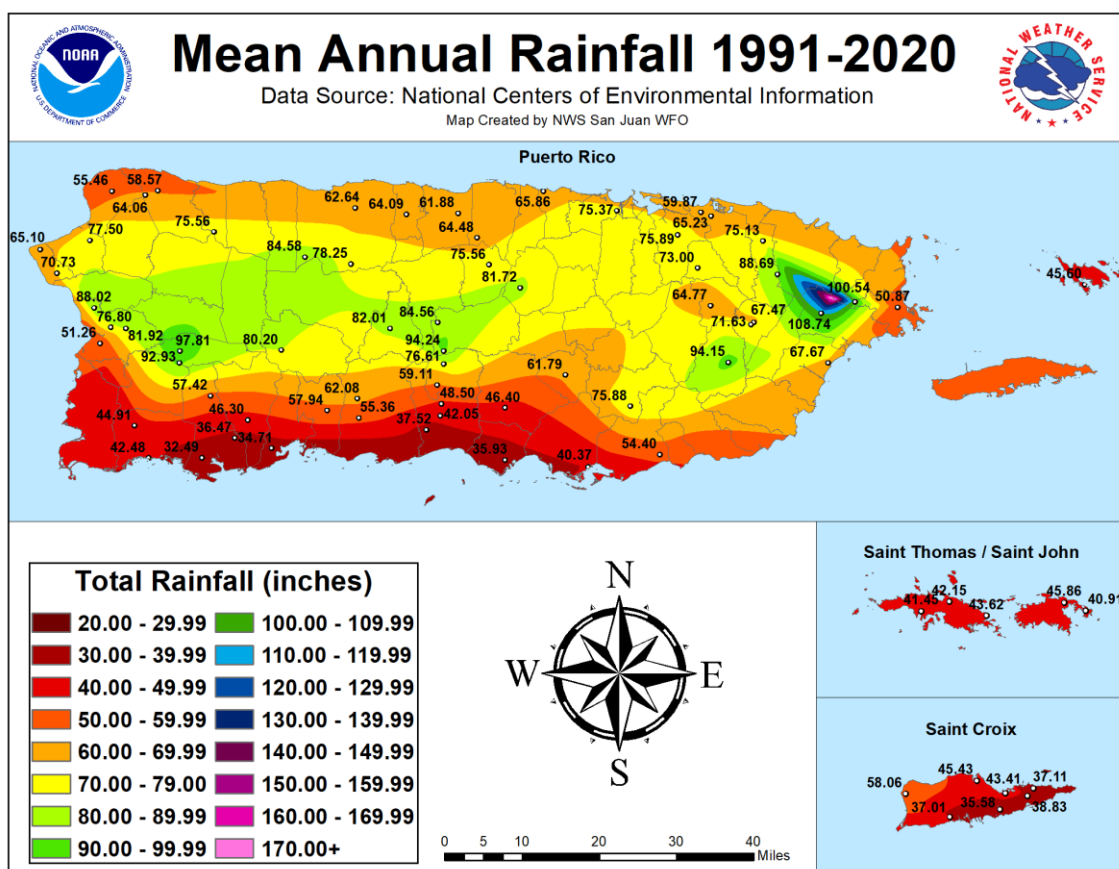
SPCS PR & VI NAD83



4.7.1.4 Future Event Probabilities

Although landslides can also result from earthquakes or human activities, most landslides in Puerto Rico are triggered by rainfall. As previously discussed, these events can occur during any type of rain event. Figure 14 presents the Mean Annual Rainfall for Puerto Rico and the U.S. Virgin Islands from 1991 to 2020. The Municipality of Aguada lies entirely within a zone that receives between 70 and 79 inches of rainfall annually. Given these precipitation levels, landslides are expected to continue occurring in the municipality.

Figure 14. Annual Rainfall 1991-2020 (PR & USVI)



Obtained from https://www.weather.gov/sju/climo_pr_usvi_normals

4.7.2 Risk Analysis

4.7.2.1 Estimated Losses

In the Municipality of Aguada, as in many other parts of Puerto Rico, landslides most

often occur during or immediately after major storms that produce intense, prolonged rainfall. Rainfall-induced landslides are closely linked to severe weather systems or consecutive rain events that saturate steep and vulnerable soils.

At present, no standardized models exist to quantify structural or content losses resulting from landslides or other mass-movement events. Consequently, USGS susceptibility indices were applied empirically using the best available data to estimate potential impacts from these hazards in Aguada . These indices classify risk into four levels: low, moderate, high, and very high. Due to data limitations, it is not currently possible to calculate monetary losses associated with building damage.

4.7.2.2 Lifelines and Critical Infrastructure

Landslides can impact FEMA Lifelines in the following ways:

- **Safety and Security:** Landslides can trap and injure or kill individuals through rapidly moving debris, hinder rescue operations, and create life-safety risks when emergency services become isolated or damaged (Center for Disaster Resilient Communities, n.d.).
- **Food, Hydration, and Shelter:** Landslides can destroy homes and agricultural areas, resulting in displacement and increased food insecurity. They may also disrupt local water and sanitation systems, heightening contamination risks, especially within temporary shelter environments (IFRC, 2023).
- **Health and Medicine:** Landslides can cause direct injuries such as trauma or suffocation, while longer-term impacts may include outbreaks of waterborne and vector-borne diseases, as well as psychological distress and trauma among survivors (Center for Disaster Resilient Communities, n.d.).
- **Energy:** Landslides can severely damage power lines, electrical substations, and fuel supply infrastructure, resulting in widespread power outages that hinder both public services and emergency response operations.
- **Communications:** Damage to communication cables, fallen utility poles, and restricted access to telecommunications infrastructure can disrupt alert and warning systems, hinder coordination among emergency responders, and impair public information networks.
- **Transportation:** Landslides can render roads, railways, bridges, and tunnels impassable or destroy them entirely as debris obstructs critical routes, severely limiting mobility for the public and restricting access for emergency response services.

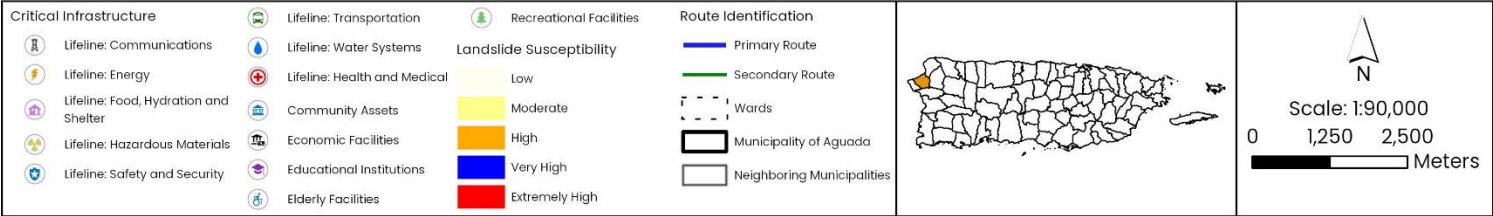
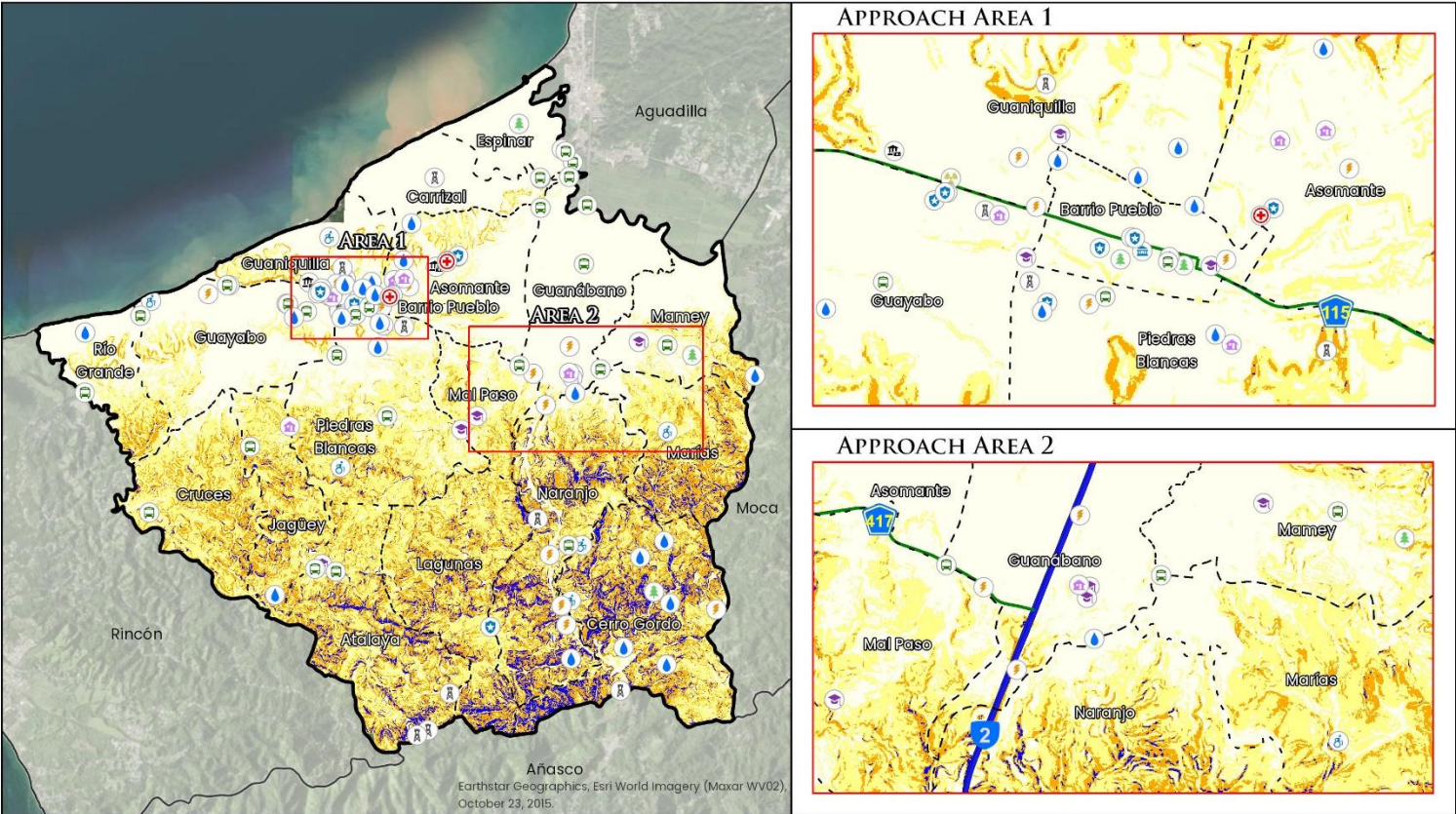
- **Hazardous Materials:** Landslides can rupture containment structures, pipelines, storage tanks, or industrial facilities, leading to the release of hazardous chemicals or pollutants and potentially triggering HAZMAT emergencies (FEMA, 2024).
- **Water Systems:** Landslides can damage water intakes, treatment plants, distribution lines, and wastewater collection and treatment facilities, leading to contamination, reduced water pressure, and significant service interruptions (IFRC, 2023).

Map 24 shows the identified critical infrastructure that could be affected by landslides. Most of the municipality's critical infrastructure is concentrated within and around the urban center of Aguada, including Barrio Pueblo, Asomante, Guaniquilla, and Carrizal, where landslide susceptibility is generally low to moderate.

Areas of high and very high landslide susceptibility are primarily located in the southern and southeastern portions of the municipality, particularly within Marías, Naranjo, Cerro Gordo, Atalaya, Lagunas, and portions of Mamey. Although fewer critical facilities are located within these areas, several transportation corridors and utility assets traverse zones susceptible to slope failures.

The most vulnerable lifeline in the event of a landslide is Transportation, as slope failures could obstruct roadways connecting the urban center and the northern coastal areas with the southern and southeastern wards of the municipality. Such disruptions could limit access to critical facilities, emergency services, utilities, and surrounding communities, particularly during or following major rainfall events.

LANDSLIDE: CRITICAL INFRASTRUCTURE EXPOSURE



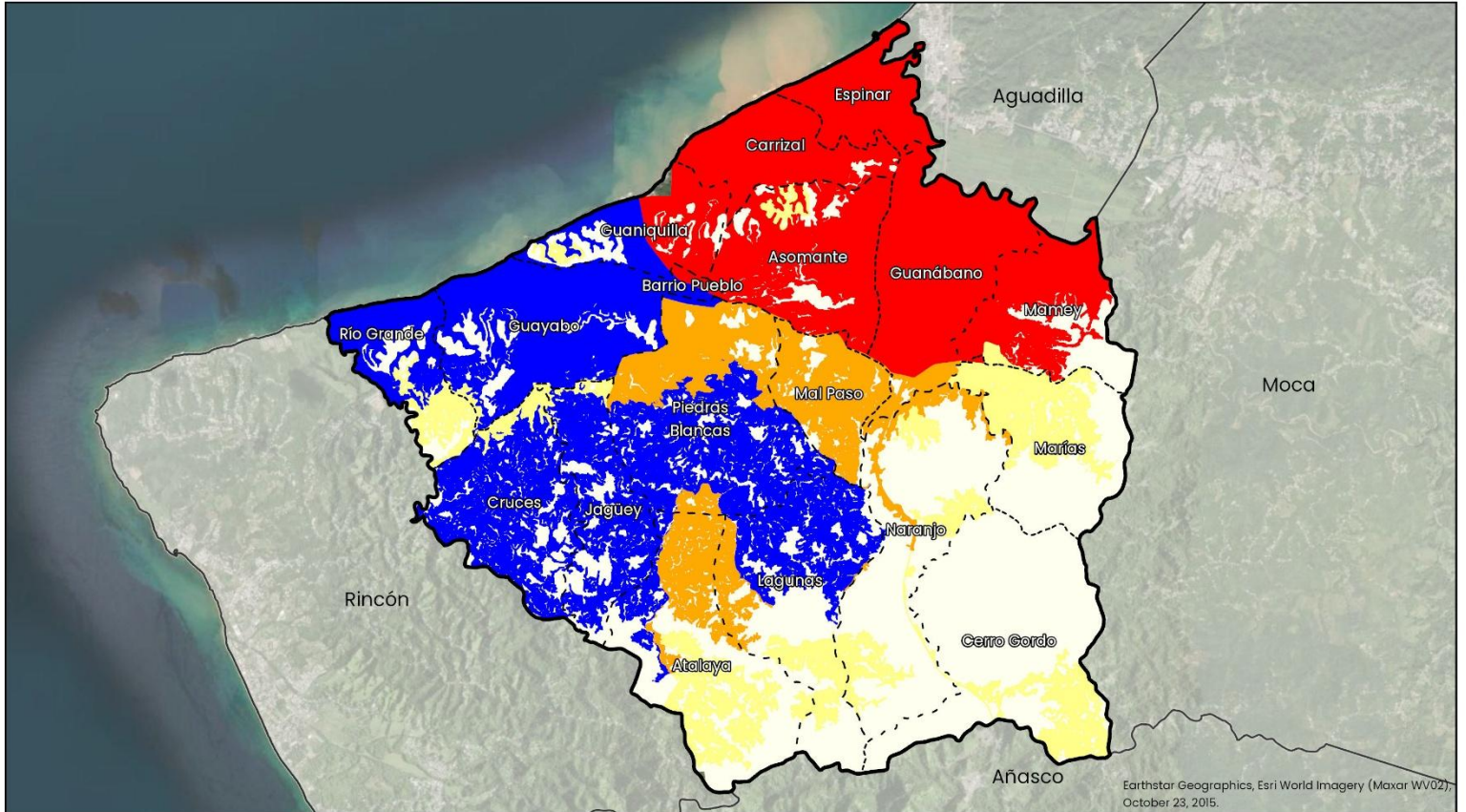
4.7.2.3 *Social Vulnerabilities*

Social vulnerability to landslides in Puerto Rico is the product of topography, poverty, aging populations, fragile infrastructure, and geographic isolation, all of which shape the severity of impacts after major storms or seismic events. Academic and federal analyses consistently show that landslides disproportionately burden communities that already struggle with access to transportation, healthcare, income stability, and emergency response. Addressing these vulnerabilities requires hazard mitigation strategies that integrate geospatial risk analysis, social vulnerability indicators, community-based planning, and infrastructure reinforcement tailored to rural and mountainous municipalities (West, Rodríguez Cruz, & Hughes, 2023).

Of particular concern, rural residents often depend on a single road that can be destroyed or blocked by slope failures, isolating entire communities. Focus groups on the municipality of Utuado highlighted that landslides cut-off access to medical facilities, emergency response, and even water and food, sometimes for months. This situation can also happen in this municipality. This creates immediate life-threatening conditions for people with health conditions, mobility limitations, or emergency medical needs (West, Rodríguez Cruz, & Hughes, 2023).

According to Map 25 the areas of high susceptibility to landslides coincide with the sections that have lower population densities.

LANDSLIDE: POPULATION EXPOSURE



Source: Puerto Rico Planning Board, Hazus 6.1 Output and Census Tract

SPCS PR & VI NAD83



4.7.2.4 *Natural and Cultural Resources*

Landslides are among the most destructive natural hazards, producing impacts that extend far beyond the immediate physical damage they cause (Eliot, Cloyd, & Philbin, 1994). Their effects on natural resources are profound and often irreversible. When a landslide occurs, vast areas of vegetation are uprooted or buried, leading to the loss of critical habitats and a decline in biodiversity. The displacement of soil not only strips away fertile layers essential for agriculture but also introduces large volumes of sediment into rivers and reservoirs. This sedimentation degrades water quality, disrupts aquatic ecosystems, and can compromise drinking water supplies. Furthermore, landslides frequently alter hydrological systems by blocking river channels, creating temporary dams that increase flood risk and modify groundwater recharge patterns.

The cultural dimension of landslide impacts is equally significant. Archaeological sites, historic monuments, and culturally significant landscapes are highly vulnerable to burial or destruction during such events. These losses are irreplaceable, erasing tangible links to the past and diminishing cultural heritage. In many regions, landslides have damaged centuries-old structures, including churches, colonial buildings, and sacred sites, resulting in costly restoration efforts or permanent loss. Beyond physical damage, the alteration of cultural landscapes such as terraced fields or ceremonial grounds undermines community identity and traditions deeply tied to the land. Economically, these impacts ripple through local economies dependent on cultural tourism, reducing visitor numbers and income for communities that rely on heritage-based activities.

Unlike the municipality's southern and southeastern wards, where the highest landslide susceptibility is concentrated, Aguada's primary historic and cultural resources, including the historic town center in Barrio Pueblo, the Parroquia San Francisco de Asís, and the Ermita de Espinar, are generally located within areas of low to moderate landslide susceptibility. As a result, these resources are considered less vulnerable to landslide hazards than facilities and infrastructure located within the municipality's mountainous interior.

4.7.2.5 *Future Conditions*

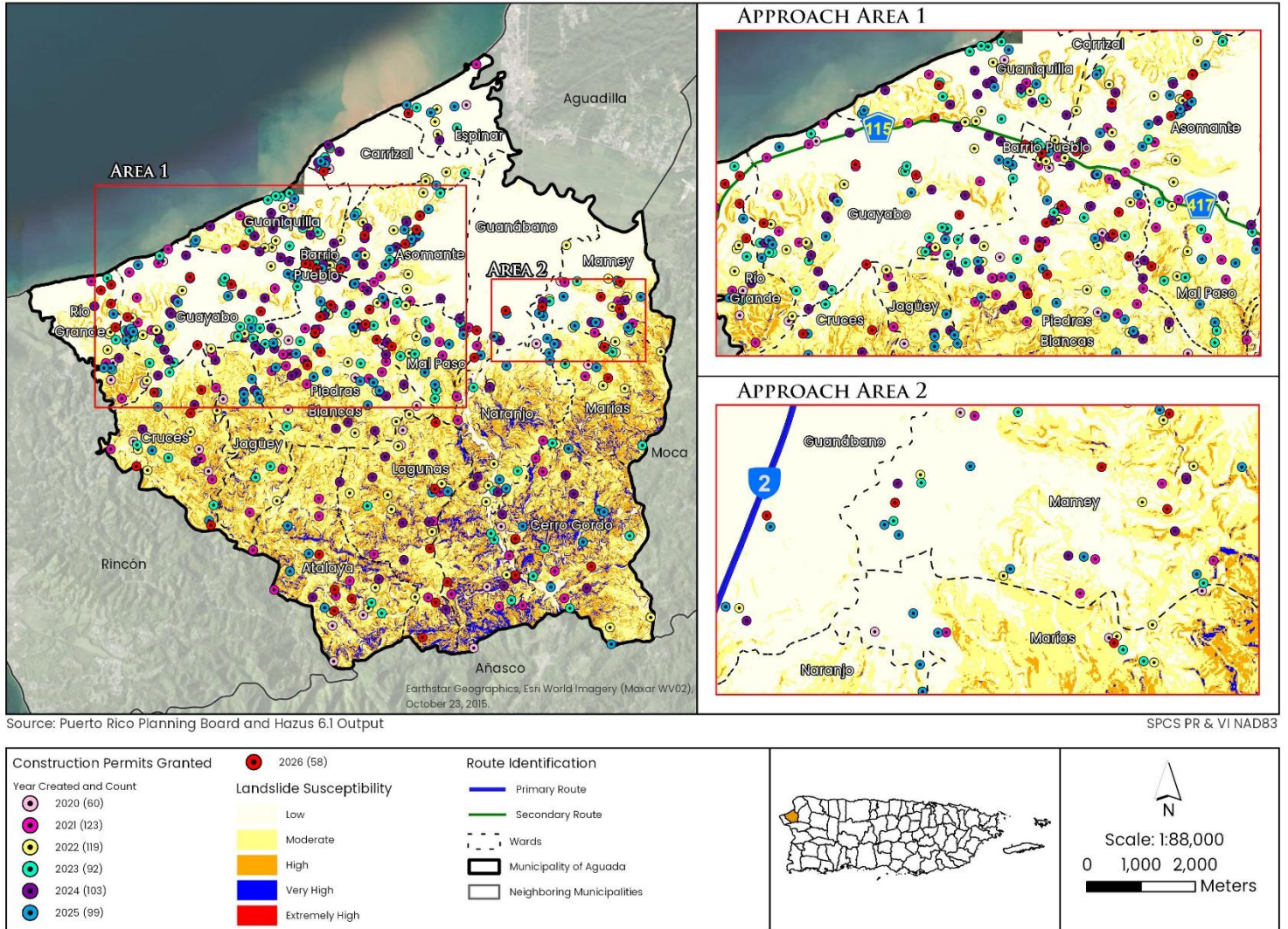
Section 3.6 above discussed the number of constructions permits issued within the Municipality. Map 26 illustrates the spatial distribution of construction permits issued between 2020 and 2026 in relation to areas of landslide susceptibility. Taken together,

these findings indicate that future exposure to landslide hazards is unlikely to diminish in the near term, as development continues throughout portions of the municipality vulnerable to slope failure.

The map shows that most recent development has occurred within the northern and central portions of Aguada, particularly in and around Barrio Pueblo, Asomante, Guaniquilla, Carrizal, Guayabo, and Guanábano, where landslide susceptibility is generally low to moderate. However, development has also occurred within areas of higher landslide susceptibility in the southern and southeastern wards of the municipality, including portions of Mamey, Marías, Naranjo, Lagunas, Atalaya, and Cerro Gordo. These areas contain steeper slopes and terrain conditions that may increase the potential for rainfall-induced landslides.

As future growth continues, additional residential, commercial, institutional, and infrastructure assets may be exposed to landslide hazards. Continued compliance with land use regulations, development controls, and appropriate slope stabilization and drainage practices will be important to reduce future landslide-related losses and enhance community resilience. The incorporation of best management practices, such as vegetation management, reforestation, bioengineering techniques, and erosion control measures, may further help reduce slope instability and improve long-term resilience in susceptible areas.

LANDSLIDE: RECENT DEVELOPMENT EXPOSURE



4.8 Tsunami

4.8.1 Description (B1-a)

A tsunami, or tidal wave, is a series of waves typically caused by a vertical displacement of the ocean floor resulting from an underwater earthquake. Tsunamis can also be triggered by submarine landslides or volcanic eruptions in a specific region. The characteristics of a tsunami vary depending on whether the wave is moving through deep water or approaching the shore. In deep waters, these waves can travel at speeds of up to 500 miles per hour and appear as low waves, generally less than one foot above sea level, often unnoticed by vessels at sea. The distance between wave crests is usually very wide. As the waves near coastal areas, their speed decreases significantly while their height increases dramatically because the wave frequency rises as its amplitude diminishes. This phenomenon can produce massive waves, sometimes exceeding 98 feet in height. However, tsunamis are often sudden, large surges in sea level along the coast, resembling a powerful tide rushing inland. Additional warning signs may precede a tsunami. These include a noticeable retreat of the sea—where water recedes from the shore—or a rapid and excessive rise in coastal sea level. Typically, a loud roar from the ocean can be heard, similar to the sound of a low-flying aircraft. Other noises may occur as powerful waves crash against reefs, rocks, and objects dragged by the current.

Although tsunami hazards cannot be prevented, municipalities can implement mitigation measures through individual and collective preparedness, maintain alert systems to warn vulnerable communities, and ensure an effective response after such an event. In Puerto Rico, efforts have been coordinated under the National Tsunami Hazard Mitigation Program (NTHMP) at the University of Puerto Rico at Mayagüez (UPRM) and by UNESCO's IOCARIBE for regional areas. This program aims to reduce tsunami impacts through disaster assessment, alert messaging guidance, and mitigation strategies. NTHMP develops tsunami inundation maps, disseminates information through media for community drills, and promotes awareness of past events. Mitigation efforts include improving information dissemination, reducing risks, creating evacuation plans, producing educational materials, and implementing NOAA's Tsunami Ready Program, among other initiatives.

4.8.1.1 Affected Area (B1-b)

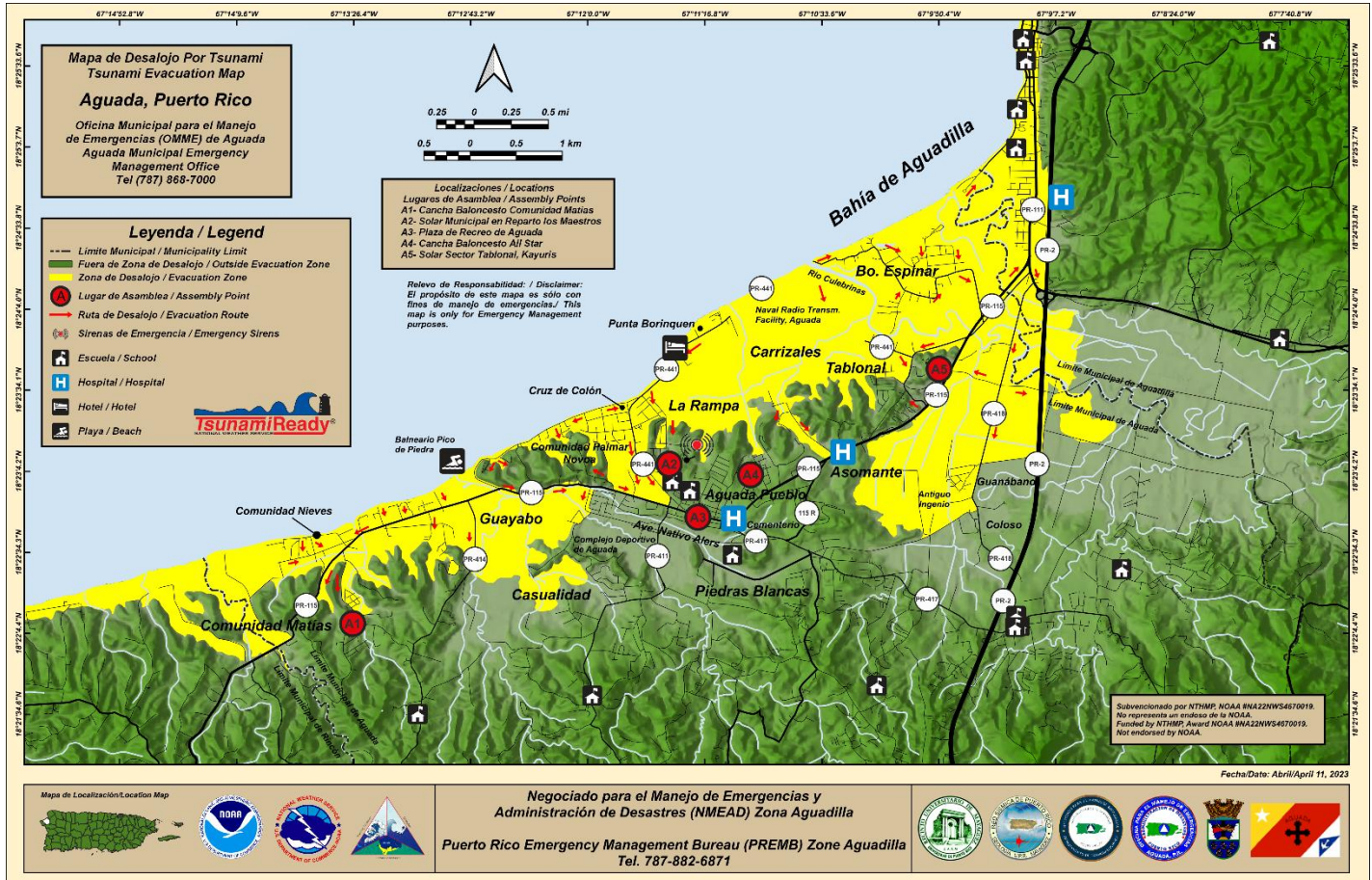
The Aguada Tsunami Evacuation Map shown in Figure 15 identifies the low-lying areas

of the municipality that are vulnerable to tsunami inundation. The evacuation zone, highlighted in yellow, extends across much of Aguada's northern sector and includes communities such as Matías, Guayabo, La Rampa, Carrizales, Tablonal, Asomante, and Espinar. Areas shown in green represent higher elevations that are generally outside the evacuation zone and serve as safer locations during a tsunami emergency.

Figure 15 provides designated evacuation routes, marked by red arrows, that direct residents and visitors inland toward higher ground. Five official assembly points (A1-A5) are strategically distributed throughout the municipality to support emergency response and public safety operations. Critical facilities, including hospitals, schools, hotels, beaches, and emergency sirens, are also identified to assist with preparedness, evacuation planning, and emergency coordination.

Overall, the map highlights tsunami vulnerability across Aguada's low-elevation northern corridor, particularly in communities located near PR-115, PR-441, and PR-442. The evacuation strategy focuses on moving residents and visitors away from these at-risk areas and toward higher inland terrain and designated assembly points following a tsunami warning or a significant seismic event.

Figure 15. Tsunami Evacuation Map



4.8.1.2 Risk Magnitude (B1-c)

Tsunami events rank among the most severe natural disasters. Among the hazards associated with a tsunami event are the following:

- Flooding of low-lying coastal areas: This occurs when tsunami waves penetrate inland, causing property destruction and fatalities due to drowning.
- Damage to coastal properties and buildings: Homes and structures located near the shoreline can suffer severe damage, rendering them uninhabitable. Additionally, these waves cause significant coastal erosion and undermine building foundations by washing away sand and soil, increasing their reach and force.

Floating debris and large objects: A tsunami can carry debris or even large vessels

inland, creating additional hazards and potentially causing major accidents and further tragedies.

Although this natural phenomenon moves slowly across the ocean, the force of a tsunami's waves can cause thousands of deaths and extensive property damage, including homes, critical facilities, and municipal infrastructure. If the disturbance originates near a coastal area, the tsunami can devastate the community within minutes (NOAA, n.d.). Developing and implementing an early warning system is essential to mitigate or reduce the impacts of such events. Likewise, it is critical that communities vulnerable to tsunamis are prepared to respond promptly and effectively once an alert is issued (NOAA, n.d.).

In 1995, the U.S. Congress designated NOAA to lead the National Tsunami Hazard Mitigation Program (NTHMP). This program represents a federal-state partnership that includes NOAA, FEMA, the U.S. Geological Survey, and 28 states and territories. Its primary goal is to reduce tsunami impacts on U.S. coasts through activities such as public education and awareness, community-level planning, risk assessments for specific areas, and guidance on tsunami alerts (NOAA, n.d.).

The TsunamiReady Program, created by NOAA's National Weather Service, aims to minimize loss of life and property from tsunamis and promote preparedness. In Puerto Rico, the Seismic Network (RSPR) manages funds for both the NTHMP and TsunamiReady Program, in coordination with the NWS Forecast Office in San Juan, FEMA, PREMB, Municipal Emergency Management Offices (OMMEs), and local communities.

Currently, 46 municipalities across the island participate in the TsunamiReady Program, including Aguada, which has both a tsunami evacuation map and TsunamiReady certification.

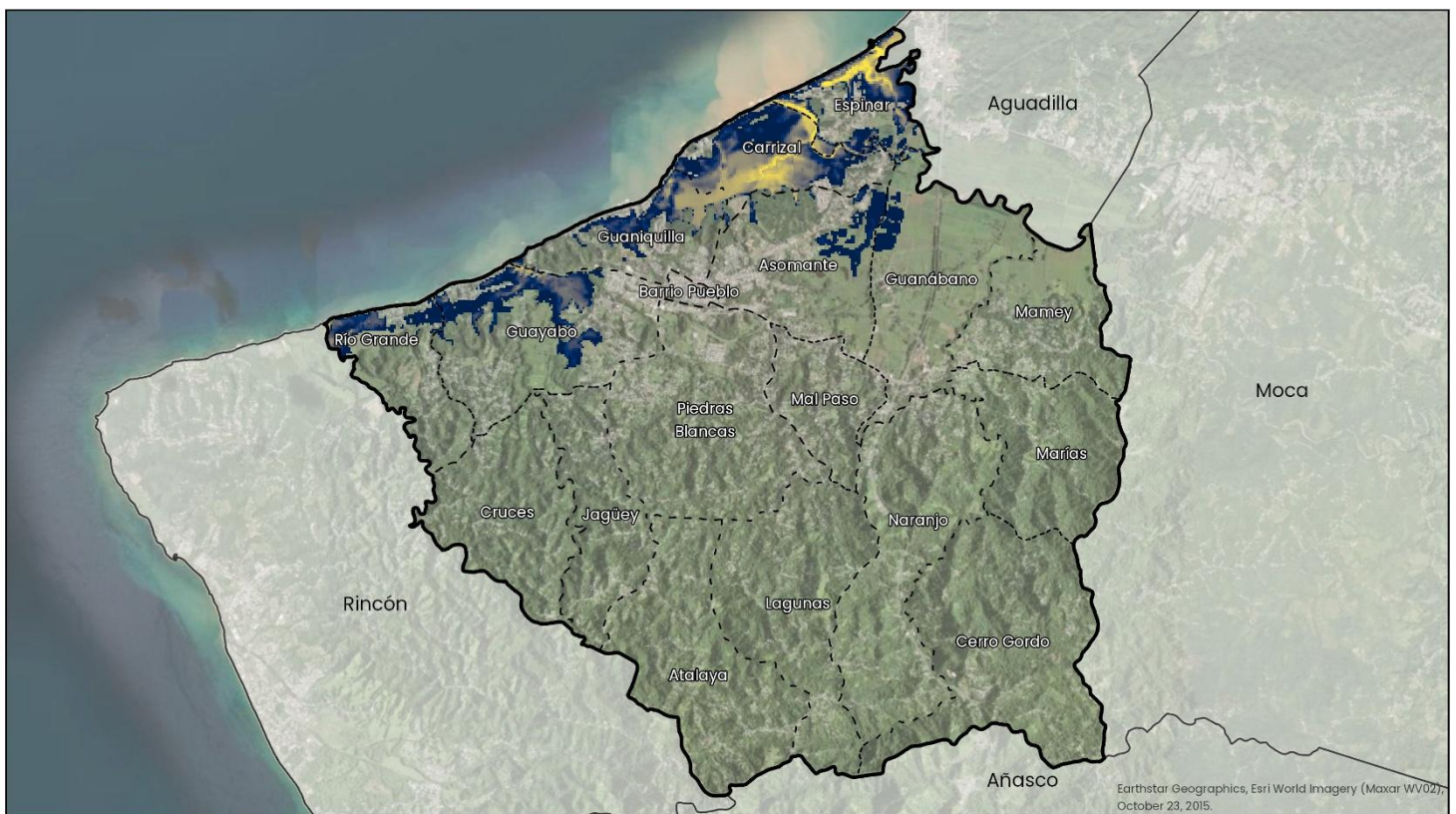
Map 27 shows the modeled tsunami inundation area concentrated along Aguada's northern coastal plain, particularly within the coastal wards of Espinar, Carrizal, Guaniquilla, Grande River from Añasco, and portions of Guayabo and Barrio Pueblo. The map indicates that tsunami inundation is generally limited to low-lying coastal areas, while the central and southern sectors of the municipality are located outside the projected impact area due to their higher elevations and greater distance from the coastline.

Map 28 shows the modeled tsunami momentum flux concentrated within the same

northern coastal areas identified in the inundation analysis, including Espinar, Carrizal, Guaniquilla, Grande River from Añasco, and portions of Guayabo and Barrio Pueblo. These areas are expected to experience the highest tsunami flow forces, indicating a greater potential for damage to exposed structures and infrastructure. In contrast, the municipality's central and southern sectors remain largely outside the projected high-impact zone due to their higher elevations and inland location.

Map 27. Tsunami Impact Area

TSUNAMI: IMPACT AREA



Median Inundation Depth (ft)



Wards

Municipality of Aguada

Neighboring Municipalities

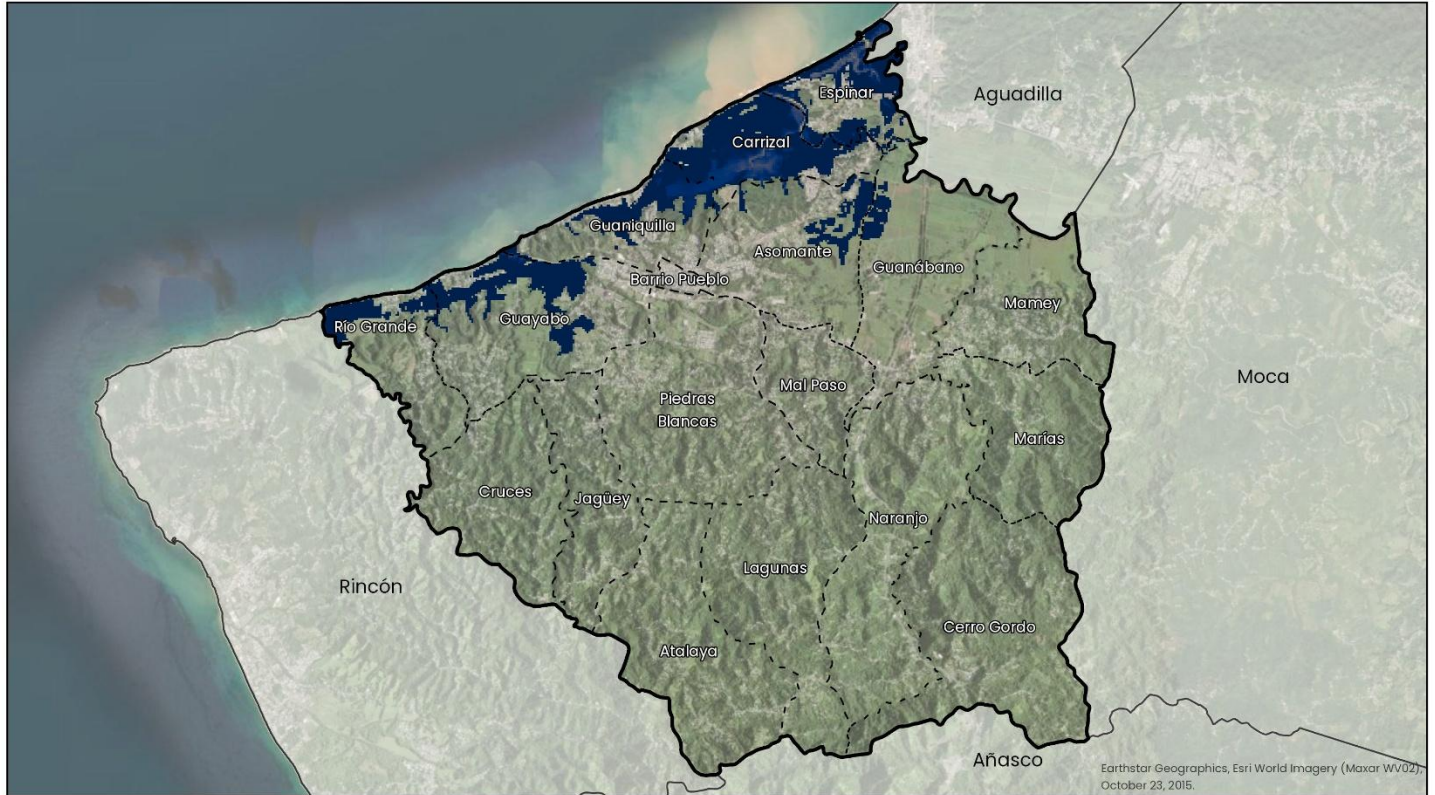


Scale: 1:80,000

0 1,000 2,000 Meters

Map 28. Tsunami: Momentum Flux (Flow Force Indicator)

TSUNAMI: MOMENTUM FLUX (FLOW FORCE INDICATOR)



Source: Puerto Rico Planning Board and Hazus 6.1 Output

SPCS PR & VI NAD83



4.8.1.3 Past Events (B1-d)

The following table show the most recent recorded Tsunami Events in Puerto Rico.

Table 24. Tsunami events in Puerto Rico

Tsunami Event	Description
1946 Tsunami	In Puerto Rico, the sea receded at Aguadilla (24 m) and Mayagüez (76 m) before returning as destructive waves. The combined earthquake and tsunami resulted in 75 fatalities and left 20,000 people homeless. At San Juan, the tsunami was recorded on a tide gauge 35 minutes after the earthquake, following a second shock (Ms 7.9) nearly as strong as the August 4 quake but located about 100 km to the northwest. The waves were also detected at distant locations, with travel times of 2:02 hours to Bermuda, 4:02 to Daytona Beach, and 4:42 to Atlantic City (Lander, Whiteside, & Lockridge, 2002).
1918 Tsunami	On October 11, 1918, Puerto Rico experienced one of the most powerful earthquakes in its history. Official reports indicate that 116 people lost their lives, and economic losses were estimated at \$4 million—twice the island’s annual budget at the time. The earthquake generated a tsunami that struck the island’s western coast within minutes of the initial shaking. Waves reached heights of up to 20 feet, at the island’s northwestern corner, appearing almost immediately after the quake. Approximately 40 of the fatalities were attributed to the tsunami itself (PRSN, 2025). In all areas where the wave was observed, witnesses reported that the sea first receded, exposing reefs and sections of the seabed never seen before, even during the lowest tides. The water then surged back, reaching equally high levels. In some locations, the large wave was followed by one or two smaller ones, and in enclosed bays, the water remained turbulent for some time. At Punta Borinquen in Aguadilla, the lighthouse keeper noted that the water began to recede during the earthquake and later rose to 15 feet. Near Punta Aguejereada, the wave reached between 18 and 20 feet, arriving 4 to 7 minutes after the quake. In Aguadilla, 32 people drowned, and nearly 300 beachside huts were destroyed. The tsunami reached Mayagüez about 20 minutes after the earthquake, with a height of approximately 5 feet (PRSN, 2025).
1867 Tsunami	On November 18, an earthquake of magnitude 7.3 was felt strongly in the Virgin Islands and the eastern region of Puerto Rico. The epicenter was in the Anegada Passage, between the islands of St. Thomas, St. Croix, and Vieques. The resulting tsunami reached heights of nearly 20 feet in St.

Tsunami Event	Description
	Thomas and St. Croix. At San Juan and Arroyo, water levels increased by approximately 0.9 to 1.5 meters, accompanied by significant wave activity near the Vieques Islands. In Fajardo, only a minor wave was documented, whereas in Yabucoa, a pronounced sea withdrawal occurred prior to a return surge that penetrated approximately 137 meters inland (Lander, Whiteside, & Lockridge, 2002). No fatalities were recorded (Castro Rivera, Proyecto 1867, n.d.).

4.8.1.4 *Future event probabilities (B1-e)*

The occurrence of a tsunami cannot be predicted, nor can its timing be determined with precision. However, because tsunamis are closely associated with seismic events such as earthquakes, their future likelihood depends on the probability of future seismic activity. Vulnerability studies have estimated a 33% to 50% probability of experiencing strong ground shaking (Modified Mercalli Intensity VII or higher) in different parts of the island within a 50-year period (PRSN, n.d.). Consequently, given that the areas of greatest seismic activity around Puerto Rico are located underwater to the northwest southeast and southwest of the island, it is plausible that the next significant earthquake could generate a tsunami.

Earthquakes and tsunamis are relatively infrequent phenomena, and not all earthquakes generate tsunamis. Nevertheless, when a major earthquake occurs beneath the ocean floor, the likelihood of a tsunami increases substantially. This implies that the probability of a tsunami is directly correlated with the probability of a strong earthquake, particularly in coastal areas. This probability serves as a key parameter for risk classification, based on historical records and contributions from planning committees and existing studies.

4.8.2 *Risk Analysis (B2-a, B2-b)*

4.8.2.1 *Estimated Losses*

The FEMA National Risk Index (NRI) provides estimates of tsunami exposure and expected annual losses for the municipality. Exposure represents the value of buildings and population located within areas potentially affected by a tsunami event.

Although tsunami hazards in Aguada are primarily limited to the municipality's

northern coastal plain, the exposure analysis indicates that a substantial amount of development and population is located within the modeled inundation area. Residential communities, businesses, transportation corridors, and utility infrastructure located near the coast contribute to a total exposure value exceeding \$665 million in building assets. In addition, approximately 3,974 residents are located within the potentially affected area, highlighting the importance of evacuation planning and public preparations.

Table 25 summarizes the municipality's exposure to tsunami hazards.

Table 25. Tsunami Exposure

Exposure - Impacted Area (sq mi)	Exposure - Building Value	Exposure - Population	Exposure - Population Equivalence	Exposure - Total
1.009811	\$665,710,022	3,973.661205	\$46,094,469,986	\$46,760,180,009

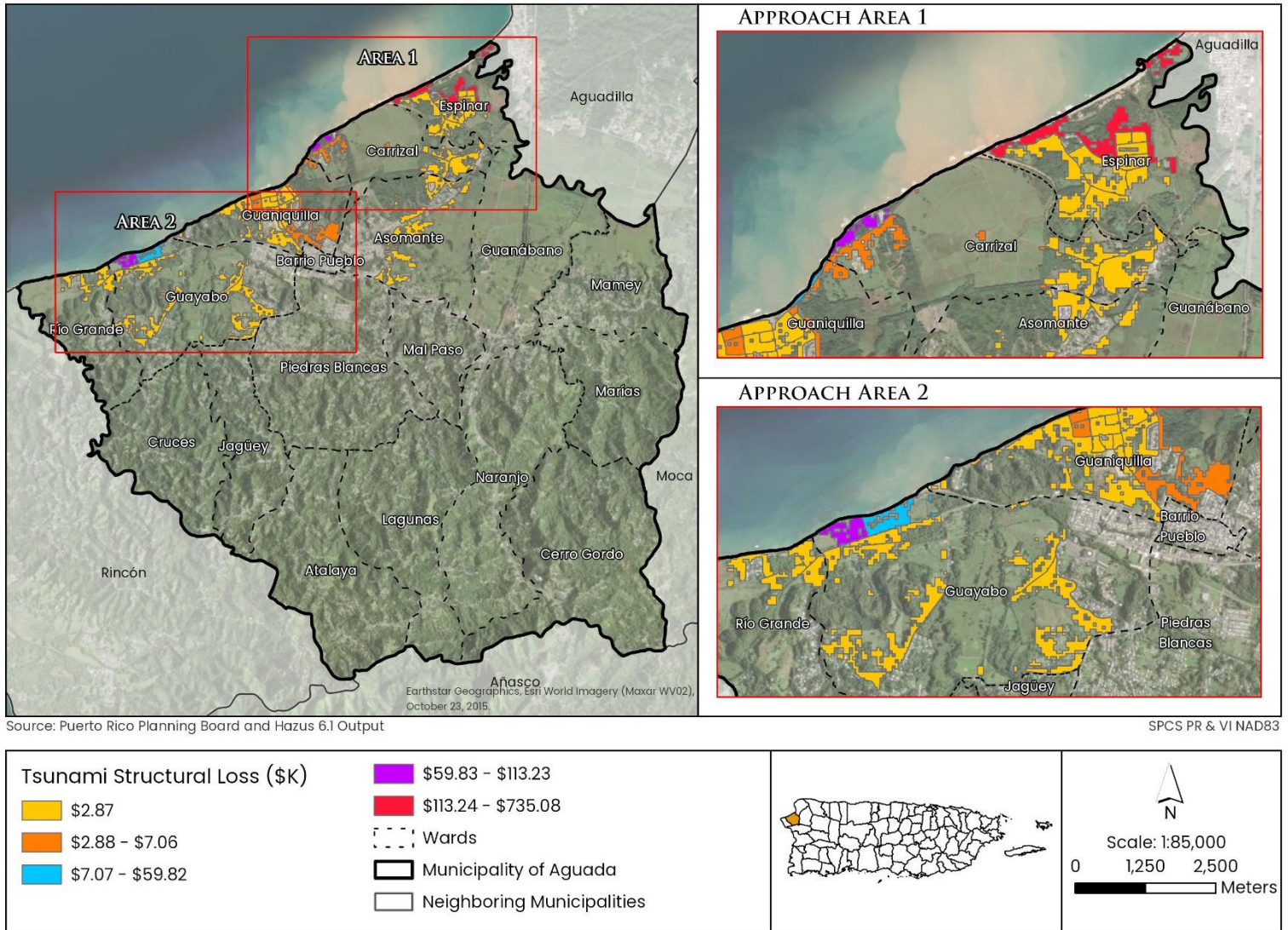
The expected annual loss for each Census tract or jurisdiction represents the average yearly economic impact, expressed in dollars, anticipated from natural hazard events. Table 26 presents the expected annual tsunami-related losses for both buildings and population.

Table 26. Expected Annual Loss to Tsunami

Expected Annual Loss - Building Value	Expected Annual Loss - Population	Expected Annual Loss - Population Equivalence	Expected Annual Loss - Total
\$371	0.000014	\$161	\$532

Map 29 illustrates the estimated tsunami-related structural losses throughout Aguada. The highest projected losses are concentrated in portions of the northern coastal wards, particularly Espinar and adjacent coastal areas, where the combination of tsunami inundation potential and developed properties results in greater damage estimates. Moderate structural losses are also identified in coastal sections of Guaniquilla, Carrizal, and Grande River from Añasco, while the central and southern portions of the municipality show little to no projected structural loss due to their higher elevations and reduced exposure to tsunami hazards. These results indicate that potential tsunami-related damages are primarily associated with low-lying coastal areas where buildings and infrastructure are concentrated.

TSUNAMI: STRUCTURAL LOSS



4.8.2.2 *Lifelines and Critical Infrastructure*

A tsunami event poses a severe and cascading threat to community functionality due to rapid onset, widespread inundation, strong currents, and extensive debris transport. Tsunamis can significantly disrupt all FEMA Community Lifelines, both immediately and over prolonged recovery periods. Lifeline impacts are often interdependent, creating compounding effects that hinder response, relief, and long-term recovery efforts (FEMA, 2021).

- The Safety and Security lifeline is critically compromised during tsunami events due to sudden flooding, debris, and limited evacuation time. Law enforcement, fire services, and emergency shelters may be damaged or rendered inaccessible by inundation or coastal erosion. Search and rescue operations are often required on a large scale, placing heavy strain on emergency responders while access routes are obstructed by debris, collapsed structures, or washed-out roadways. Additionally, damaged correctional facilities and disrupted communications can elevate secondary public safety risks (NOAA, n.d.).
- Tsunami impacts frequently contaminate potable water systems through saltwater intrusion, chemical releases, and damage to treatment facilities. Food distribution systems may be interrupted due to flooded warehouses, damaged ports, and loss of refrigeration. Housing stock in coastal and low-lying areas is particularly vulnerable; entire neighborhoods may be destroyed or declared uninhabitable due to structural damage or mold contamination. As a result, large, displaced populations require mass care, sheltering, and long-term housing solutions, significantly stressing local and regional resources (FEMA, 2020).
- Healthcare systems face immediate challenges following a tsunami, including physical damage to hospitals and clinics, loss of power, and limited access for patients and staff. Medical surges are common due to drowning, trauma, and exposure-related injuries. Public health risks increase as standing water and debris contribute to disease transmission, while ongoing disruptions to water and sanitation systems exacerbate health vulnerabilities. Long-term mental health impacts are also common among affected populations and first responders (FEMA, 2017; World Health Organization, 2019).
- Electrical substations, fuel storage facilities, and distribution infrastructure located in coastal or low-elevation areas are at high risk of inundation and corrosion damage during tsunami events. Power outages can persist for

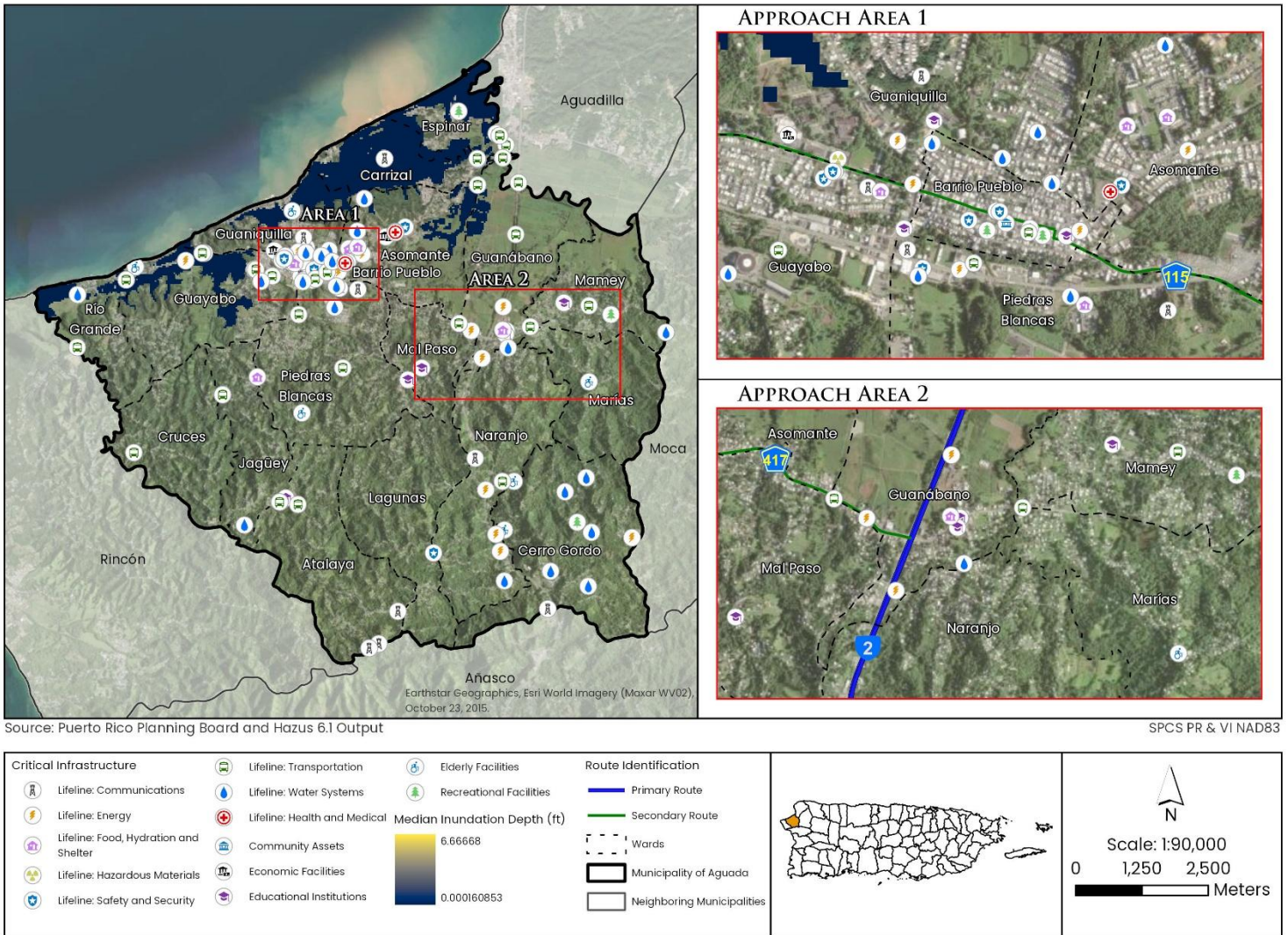
extended periods, affecting all other lifelines such as water treatment, healthcare delivery, telecommunications, and emergency operations. Fuel supply disruptions may hinder debris removal, emergency response, and generator operations, further delaying restoration efforts (FEMA, 2017).

- Tsunami waves and associated flooding can damage fiber-optic lines, cellular towers, and switching facilities, resulting in widespread loss of voice and data communications. These disruptions impair emergency notifications, situational awareness, interagency coordination, and public information dissemination. Communication outages during evacuation and response phases can significantly increase risk to life and complicate rescue operations (FEMA, 2020).
- Transportation systems are among the most heavily impacted lifelines during tsunami events. Roads, bridges, ports, rail lines, and airports may be destroyed, undermined, or obstructed by debris and sediment. Port facilities are particularly vulnerable and may experience prolonged closures, affecting regional supply chains and economic recovery. Impaired transportation networks limit evacuation, emergency access, and delivery of critical supplies during response and recovery operations (NOAA, 2023).
- Water and wastewater infrastructure is highly susceptible to tsunami damage due to inundation, pipeline breaks, pump station failures, and contamination from saltwater and hazardous materials. Wastewater system failures can result in environmental contamination and public health hazards. Restoration of water service is often complex and time-consuming, particularly where underground infrastructure has shifted or corroded due to saltwater exposure (FEMA, 2017).

Map 30 illustrates the location of critical infrastructure and community lifeline facilities in relation to the tsunami impact area in Aguada. The map indicates that several facilities associated with Safety and Security, Health and Medical, Food, Hydration and Shelter, Energy, Transportation, Communications, and Water Systems lifelines are located within or near areas potentially exposed to tsunami inundation. The greatest concentration of facilities is observed within the northern portion of the municipality, particularly in and around the barrios of Guaniquilla, Barrio Pueblo, and Asomante, which coincide with the primary tsunami impact area. Additional lifeline facilities are distributed inland along major transportation corridors, including portions of Guanábano, Mal Paso, Naranjo, Mamey, and Marías. The presence of multiple lifeline facilities within the potential inundation zone highlights the possibility of cascading impacts during a tsunami event, as disruptions to one system may affect the operation and recovery of other interdependent community functions.

Map 30. Tsunami: Critical Infrastructure Exposure

TSUNAMI: CRITICAL INFRASTRUCTURE EXPOSURE



4.8.2.3 Social Vulnerabilities

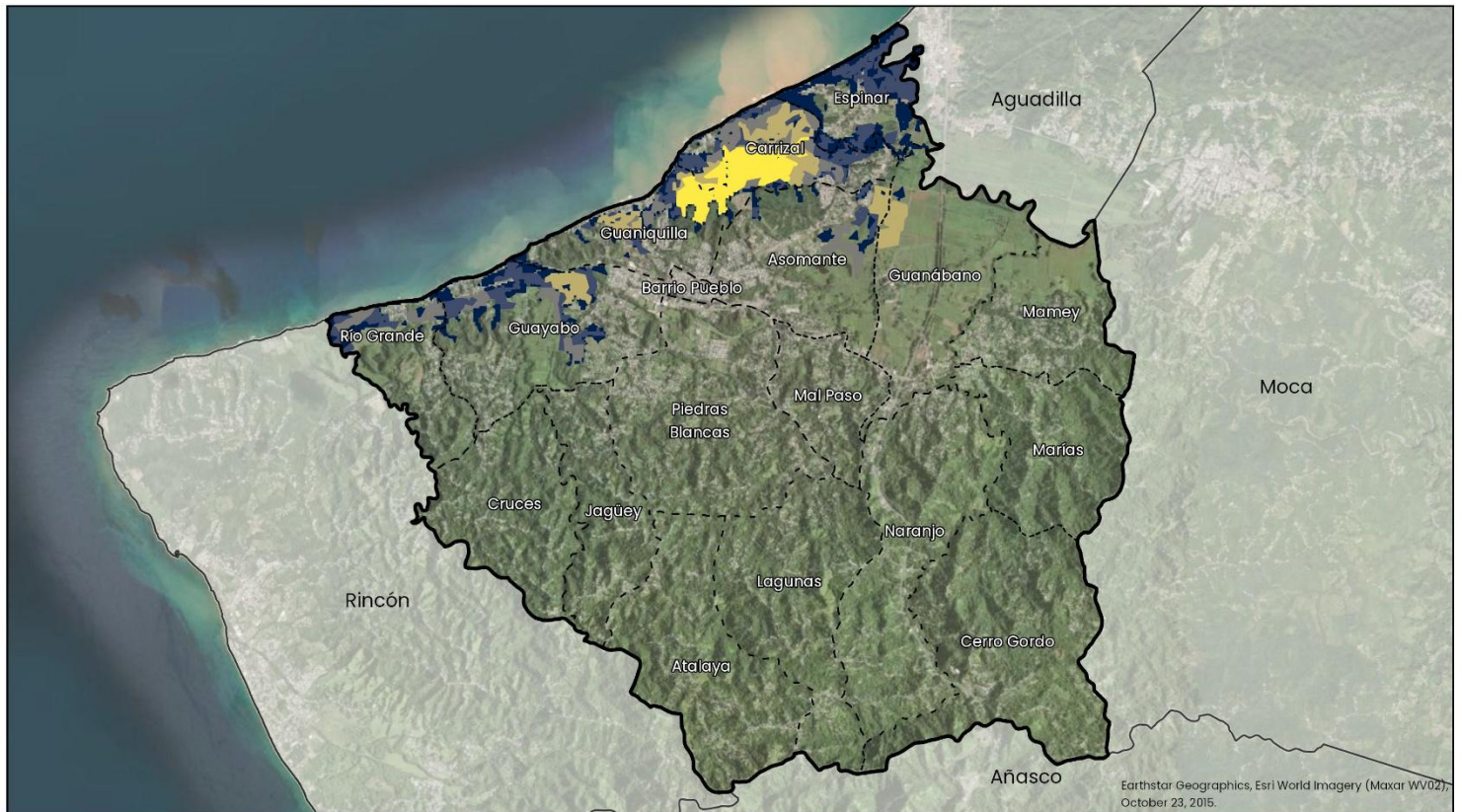
Social vulnerability during a tsunami event reflects pre-existing social, economic, and health conditions that influence how individuals and communities prepare for, respond to, and recover from rapid-onset coastal hazards. Research by U.S. scholars demonstrates that populations with lower incomes, limited access to transportation,

and residence in hazard-prone coastal zones face disproportionately higher risk during tsunami evacuations (Cutter, Boruff, & Shirley, 2003). Older adults and people with disabilities are particularly vulnerable due to reduced mobility, dependence on medical and social support systems, and challenges accessing timely warnings and evacuation assistance (Peek & Stough, 2010)). Studies of community resilience further show that inadequate risk communication, lack of hazard awareness, and weak institutional planning can significantly amplify disaster impacts, even when physical exposure is similar (Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2007). Language barriers and social isolation may delay protective actions, increasing mortality and injury risk during time-compressed tsunami events. Collectively, these factors produce uneven disaster outcomes and underscore the importance of integrating social vulnerability considerations into tsunami preparedness and emergency planning.

Map 31 illustrates the population exposure to tsunami hazards in Aguada. The analysis indicates that the greatest concentrations of population at risk are located within the municipality's northern coastal zone, particularly in the Carrizal sector, where exposure values exceed 120 people in some areas. Additional pockets of exposed population are present along other low-lying coastal communities, while the interior and southern portions of the municipality show little to no tsunami population exposure. This distribution reflects the concentration of residential development near the coastline and highlights the importance of evacuation planning and public awareness efforts in coastal neighborhoods.

Map 31. Tsunami: Population Exposure

TSUNAMI: POPULATION EXPOSURE



Source: Puerto Rico Planning Board, Hazus 6.1 Output and Census Tract

SPCS PR & VI NAD83



4.8.2.4 Natural and Cultural Resources

A tsunami's waves scour coastal areas, eroding beaches, dunes, and cliffs, and reshaping geomorphology through sediment redistribution. They remove coastal vegetation, including mangroves, saltmarshes, and coastal forests, severely weakening ecological buffers against future events and disrupting habitat for wildlife.

Submerged ecosystems, such as coral reefs and seagrass beds, suffer mechanical damage or smothering from debris and sediment, reducing biodiversity and undermining fisheries (Institute for Environmental Research and Education, 2025).

Saltwater intrusion contaminates freshwater ecosystems and aquifers, compromising drinking water and agriculture. Inland, fish and other aquatic organisms are often displaced or perish due to abrupt changes in salinity, wave force, and sedimentation. Studies on the 2011 Tōhoku tsunami showed changes in seafloor sediment structure that affected benthic invertebrate activity over time, highlighting lasting ecological legacies. Overall, these effects can take years or decades to recover from, especially when compounded by diminished habitat complexity and altered physical conditions (Institute for Environmental Research and Education, 2025).

Cultural heritage in coastal regions—including historic towns, monuments, and archaeological sites—is profoundly impacted. Physical destruction often occurs due to wave forces, flooding, debris impact, and prolonged inundation. Buildings and monuments can collapse or suffer structural failure, while artifacts and intangible cultural practices may be irretrievably lost. (Okamura, et al., 2013).

4.8.2.5 Future Conditions (E1-a)

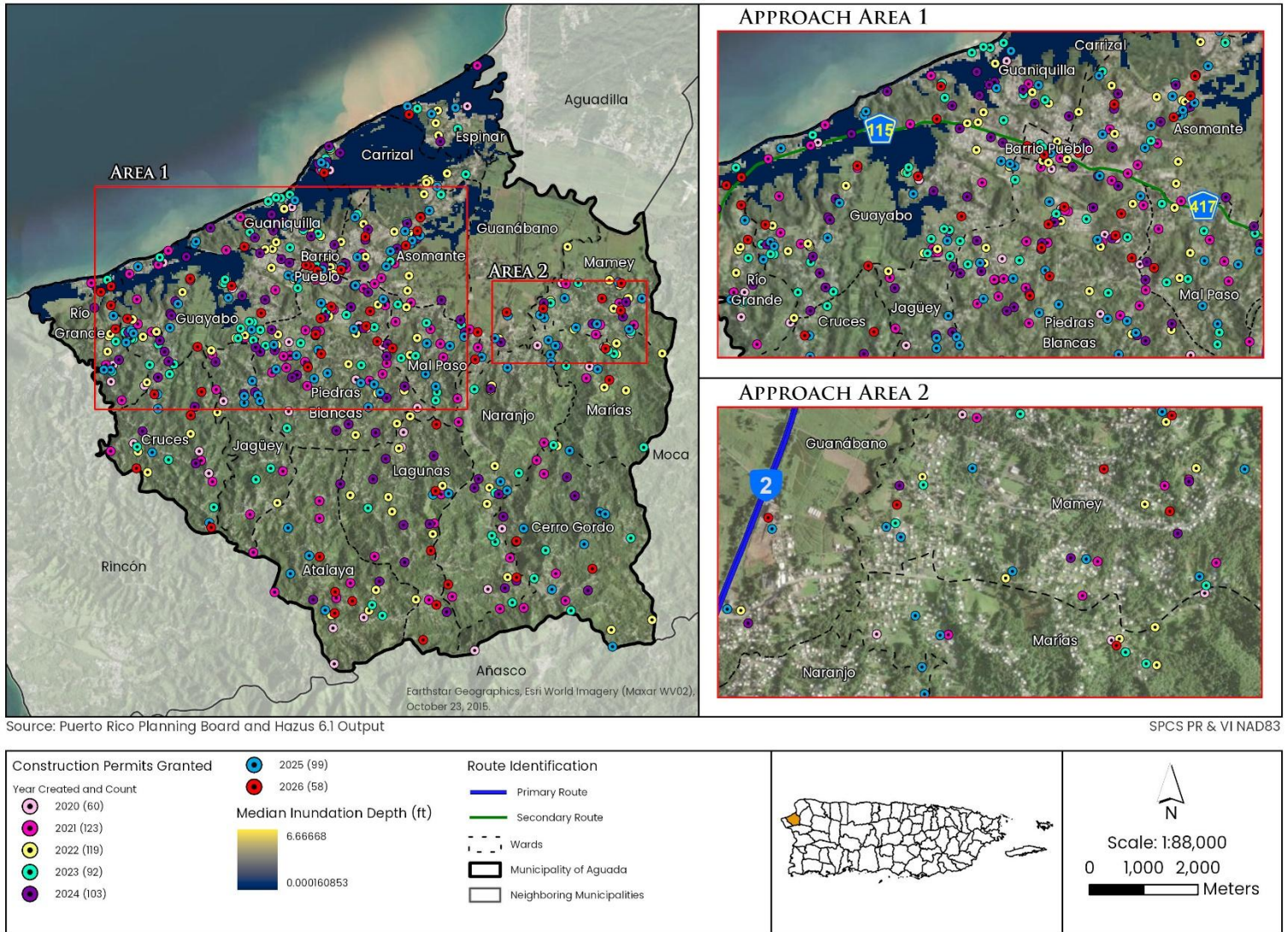
Future conditions for tsunami hazard in Aguada are influenced by ongoing development patterns and the location of new constructions relative to areas susceptible to tsunami inundations. As residential, commercial, and institutional development continues, the number of people, structures, and assets exposed to future tsunami events may increase. Understanding where recent development is occurring provides insight into potential changes in vulnerability and exposure over time.

Map 32 shows the construction permits approved within Aguada between 2020 and 2026 in relation to the tsunami impact area. The map indicates that a portion of recent development has occurred within areas potentially exposed to tsunami inundations, particularly along the municipality's northern coastal sector. Construction permits are distributed throughout the tsunami impact area, including portions of the barrios of Guaniquilla, Barrio Pueblo, Carrizal, Espinar, and Asomante. This pattern suggests that exposure within the tsunami-prone area may increase over time as new development continues in these locations. The concentration of recent permits within and adjacent to the tsunami impact area highlights the importance of incorporating hazard awareness, evacuation planning, and resilient development practices into future land

use and development decisions.

Map 32. Tsunami: Recent Development Exposure

TSUNAMI: RECENT DEVELOPMENT EXPOSURE



4.9 Flooding

4.9.1 Description (B1-a)

Floods, generally caused by excessive rainfall (FEMA, 1997), are classified into two main categories: general floods and flash floods.

- **General floods** are long-duration events that can last several days and include riverine, coastal, and urban floods. Coastal floods are associated with storm surges, waves, and heavy rains generated by hurricanes and tropical storms, while urban floods result from the alteration of natural drainage due to urban development. Riverine floods occur when rivers overflow due to excessive water runoff through rainfall or structural failures, causing water to spill into surrounding land. Flash floods often stem from stationary storms, hurricanes, or dam failures, affecting both mountainous areas and urbanized zones.
- **Flash floods** happen when prolonged rainfall falls over a watershed (water basin). The latter result from intense precipitation over a short period in specific areas. The magnitude of flash floods events depends on factors such as basin topography and physiography, weather patterns, soil saturation, and surface impermeability. Flash floods mainly originate from slow-moving storms over specific areas or from intense rainfall associated with hurricanes and tropical storms (NMEAD, 2021). However, they can also occur after the collapse of dams or levees within minutes or hours, due to extreme rainfall or the sudden release of water from retention basins or other stormwater control facilities. Although more frequent in mountain streams, these events can occur in urban areas where impermeable surfaces limit infiltration.

The periodic flooding of land adjacent to rivers, streams, and coasts—known as floodplains—is a predictable natural phenomenon based on recurrence intervals. These intervals represent the average time, in years, between events of equal or greater magnitude. The longer the recurrence interval, the greater the magnitude of the event, which implies a significant increase in risk and the extent of the affected area. Floodplains flood periodically according to recurrence intervals, defined as the average time between events of equal magnitude. For example, a 100-year flood has a 1% annual probability, while a 500-year flood corresponds to 0.2%. These frequencies are calculated through statistical analysis of historical flow records and extreme events.

Table 27 shows the different flood zone classifications for Puerto Rico adopted by the

PRPB (PRPB, 2021).

Table 27. Puerto Rico Flood Zones

Flood Zone	Description
Zone A	Special Flood Hazard Area with a recurring period of 100-years determined by using approximate methodologies with no base flood elevation or Floodway determined.
Zone AE	Special Flood Hazard Areas with a recurring period of 100-years determined by detailed methodologies with base flood elevations indicated. According to the scope of the study, may include the Floodway determination.
Zone AO/AH	Shallow Special Flood Hazard Areas with a recurring period of one hundred (100) years with a base flood depth fluctuating between 0.30 meters (one (1) foot) and 0.91 meters (three (3) feet). The average flood depths are obtained from detailed hydraulic analysis.
Zone A99	areas prone to flooding from a flooding event with a one percent (1%) annual chance of occurring. These special areas are within a flood protection or control system where enough progress has been made in its construction, even though it has not been completed, but specific statutory progress has been reached to complete it. This zone does not detail base flood elevations or flooding depths, so it is recommended to use, if required, the previous flood elevation for Zone 99. Mandatory flood insurance purchase requirements apply.
Zone D	Flooding area that is not determined but is possible.
Zone VE	Coastal high flood hazard area with a recurring period of 100-years with velocity and energy (storm surge) and a determined base flood elevation.
Zone X Shaded	flooding area with 0.2% chance of occurring each year or the 100-year flood with a water depth of less than 0.3 meters, with drainage areas of less than 2.6 square kilometers or areas protected by levees against the 100-year flood.
Zone X (unshaded)	Area determined to be outside the five hundred 500-year storm flood.

4.9.1.1 Affected Area

Flood Rate Insurance Maps (FIRM)

Flood hazard areas within Aguada are concentrated primarily in the northern portion of the municipality and extend across several wards, including Grande River from Añasco, Guayabo, Guaniquilla, Barrio Pueblo, Carrizal, Espinar, Asomante, Guanábano,

and Mamey. Smaller flood hazard areas also extend inland along mapped drainage corridors.

Map 33 illustrates the FEMA-mapped flood hazard zones within the Municipality of Aguada. The light blue areas represent the 1-percent annual chance flood hazard area (100-year floodplain), the orange areas represent the 0.2-percent annual chance flood hazard area (500-year floodplain), and the red-hatched areas identify the FEMA regulatory floodway.

The mapped flood hazard areas are distributed across a substantial portion of the municipality's northern sector and are present in both coastal and inland areas. The largest concentration of flood hazard areas occurs along the northern coastal zone, particularly within the Corrizal, Espinar, Guaniquilla, Barrio Pueblo, Asomante, Guanábano, and Mamey sectors. Additional flood hazard areas extend inland along drainage features throughout the northern half of the municipality.

The 0.2-percent annual chance flood hazard areas generally occur adjacent to portions of the 1-percent annual chance flood hazard area, while the regulatory floodway is concentrated within specific segments of the mapped floodplain. Overall, the map indicates that flood hazards affect a broad area of northern Aguada and are associated with both coastal areas and inland drainage corridors.

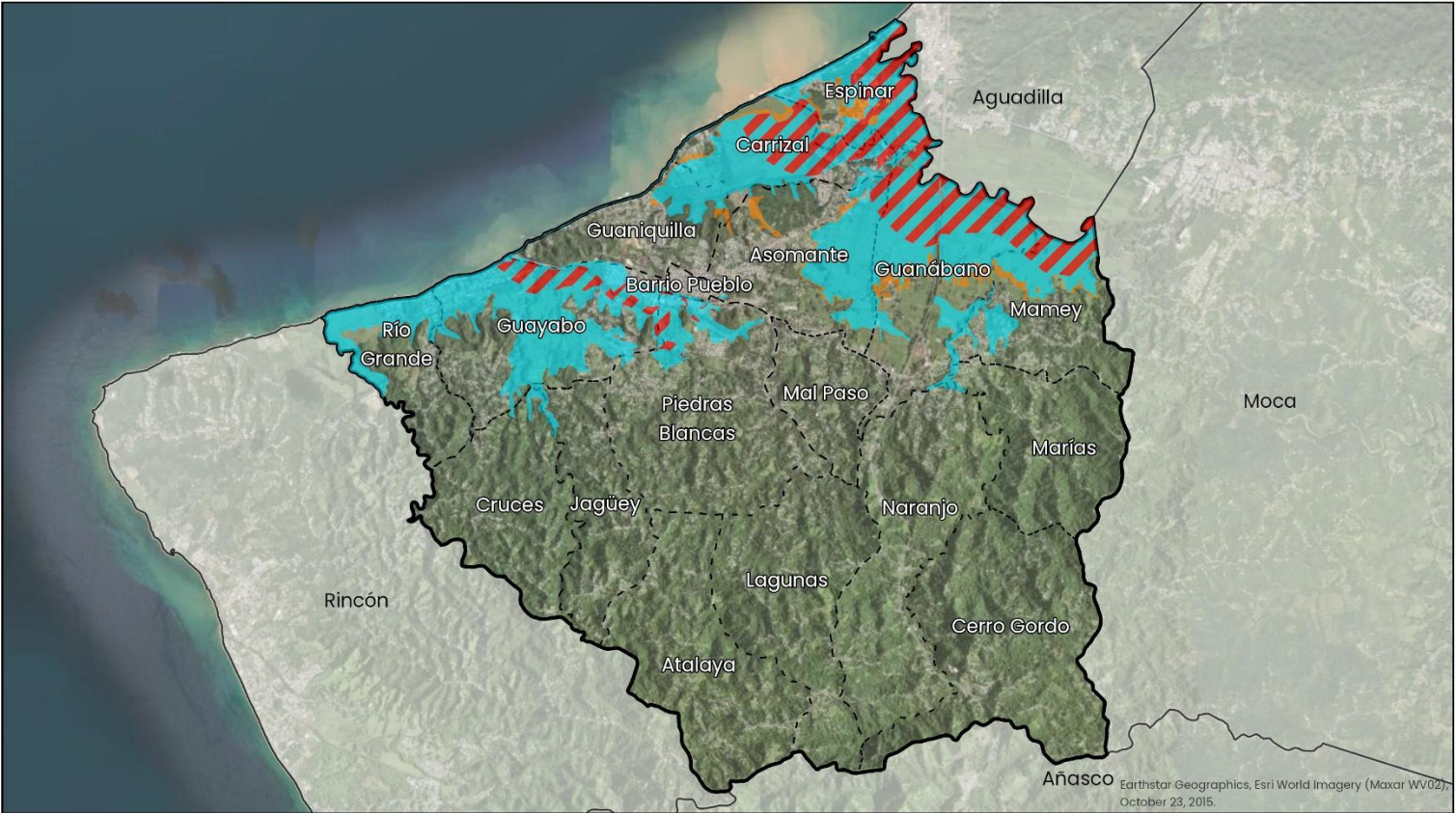
Figures 16 to 19 shows various FIRMette that shows specific areas of flooding in the Municipality.

- Figure 16 shows FEMA-designated coastal flood hazard areas along the northwestern shoreline of Aguada. The mapped VE and AO flood zones are associated with coastal inundation, storm surge, and wave action affecting low-lying coastal lands. Potential impacts include residential properties, local roads, and shoreline infrastructure located near the Atlantic coast. Coastal flooding generated by hurricanes and tropical storms may result in inundation, erosion, and temporary disruption of access to nearby communities and facilities.
- Figure 17 shows flood hazard areas associated with the Guayabo River floodplain in northern Aguada. The mapped Zone AE floodplain and regulatory floodway extend through developed areas near the coast, affecting residential communities, local roadways, and public infrastructure located adjacent to the river corridor. During major rainfall events, overflow from Guayabo River may result in roadway inundation, restricted access, and damage to nearby

properties. The proximity of the floodplain to the coastline may further increase flood risk due to drainage limitations and coastal storm influences.

- Figure 18 shows the Guayabo River floodway and surrounding floodplain affecting a highly developed area of northern Aguada. The mapped Zone AE flood hazard area encompasses residential neighborhoods, commercial establishments, local streets, and important community facilities, including the Ismael “Chavalillo” Delgado Coliseum. Flooding along the Guayabo River corridor may disrupt transportation, municipal operations, emergency response activities, and access to critical community services. The figure also shows the Aguada City Hall and the town plaza located outside the mapped flood hazard area, indicating that these key governmental and community assets are situated beyond the limits of the FEMA-designated floodplain. Due to the concentration of development within the floodplain, this area represents one of the municipality’s most significant riverine flood risk locations.
- Figure 19 shows FEMA-designated flood hazard areas associated with the lower Culebrinas River watershed and the Caño Madre Vieja coastal drainage system in northern Aguada. The map identifies extensive Zone AE floodplain areas and a regulatory floodway extending across the low-lying lands between the Río Culebrinas to the west and Caño Madre Vieja to the east. Potential impacts include residential properties, transportation corridors, and other infrastructure located within the mapped floodplain. During major rainfall events and tropical cyclones, overflow from the Culebrinas River and adjacent drainage channels may combine with coastal flooding to increase inundation depths, restrict access, and affect nearby communities.

FLOOD HAZARD ZONES



Source: Puerto Rico Planning Board and Federal Emergency Management Agency (FEMA)

SPCS PR & VI NAD83

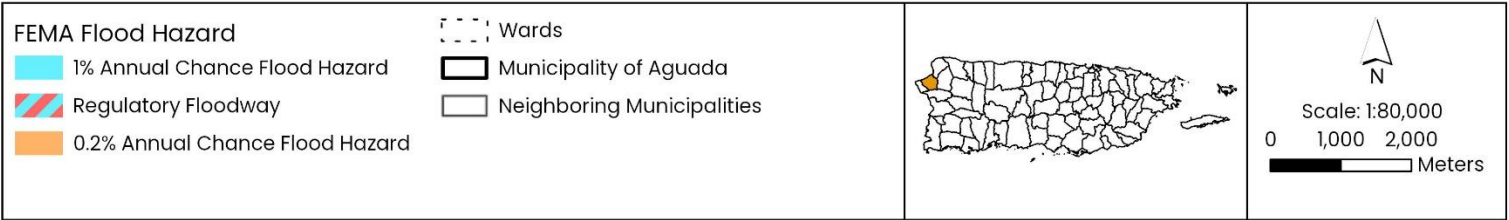


Figure 16. Northwestern Coastal Flood Hazard Area

National Flood Hazard Layer FIRMette



67°13'38"W 18°22'48"N



0 250 500 1,000 1,500 2,000 Feet 1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) Zone A, V, A99
	With BFE or Depth Zone AE, AO, AH, VE, AR
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
	Future Conditions 1% Annual Chance Flood Hazard Zone X
	Area with Reduced Flood Risk due to Levee. See Notes, Zone X
	Area with Flood Risk due to Levee Zone D
OTHER AREAS	NO SCREEN Area of Minimal Flood Hazard Zone X
	Effective LOMRs
	Area of Undetermined Flood Hazard Zone D
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer
	Levee, Dike, or Floodwall
OTHER FEATURES	20.2 Cross Sections with 1% Annual Chance Water Surface Elevation
	17.5 Coastal Transect
	Base Flood Elevation Line (BFE)
	Limit of Study
	Jurisdiction Boundary
	Coastal Transect Baseline
MAP PANELS	Profile Baseline
	Hydrographic Feature
	Digital Data Available
	No Digital Data Available
	Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

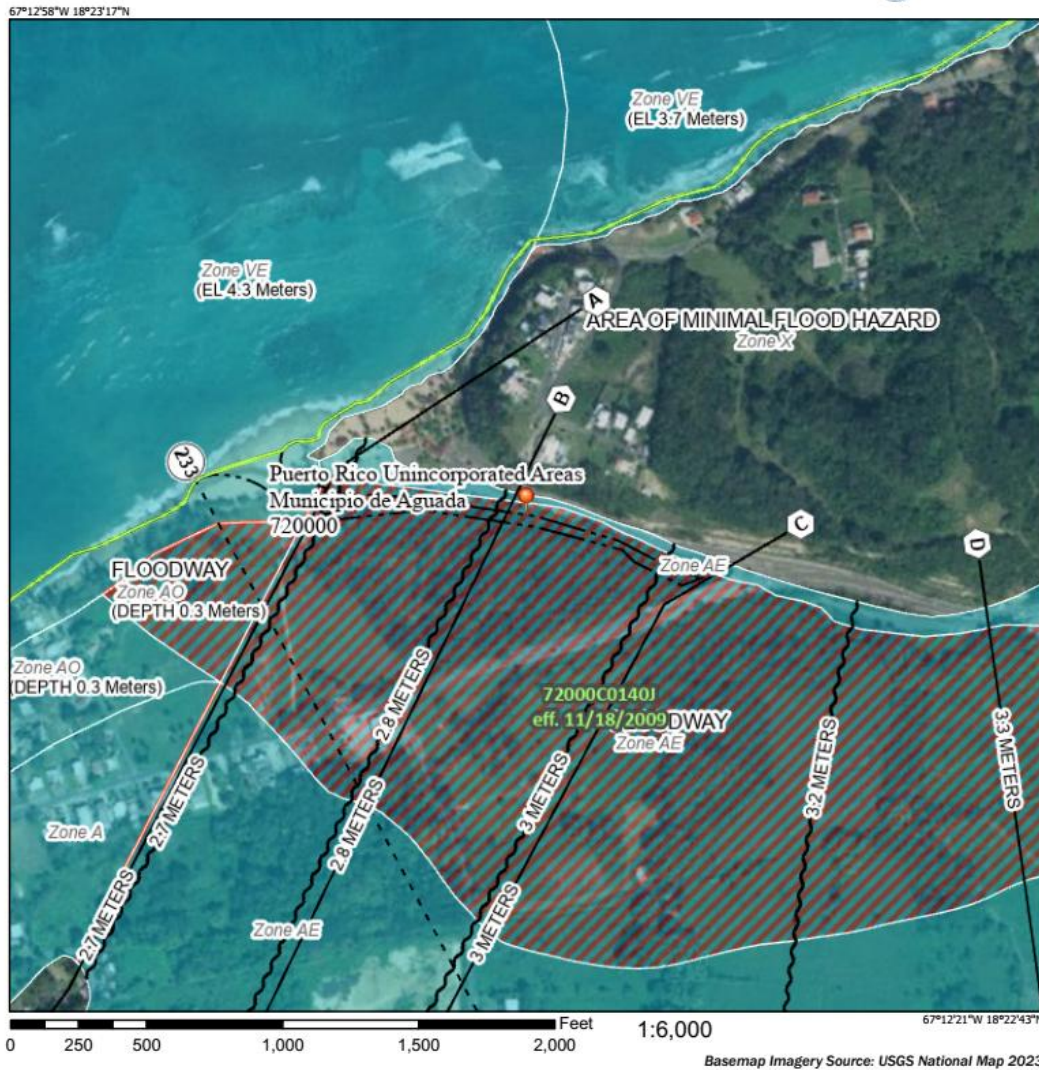
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards.

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 8/21/2026 at 11:46 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Figure 17. Guayabo River Floodway

National Flood Hazard Layer FIRMette



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS

- Without Base Flood Elevation (BFE) Zone A, V, AE99
- With BFE or Depth Zone AE, AO, AH, VE, AR
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD

- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
- Future Conditions 1% Annual Chance Flood Hazard Zone X
- Area with Reduced Flood Risk due to Levee. See Notes, Zone X
- Area with Flood Risk due to Levee Zone D

OTHER AREAS

- NO SCREEN Area of Minimal Flood Hazard Zone X
- Effective LOMRs
- Area of Undetermined Flood Hazard Zone D

GENERAL STRUCTURES

- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES

- Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS

- Digital Data Available
- No Digital Data Available
- Unmapped

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

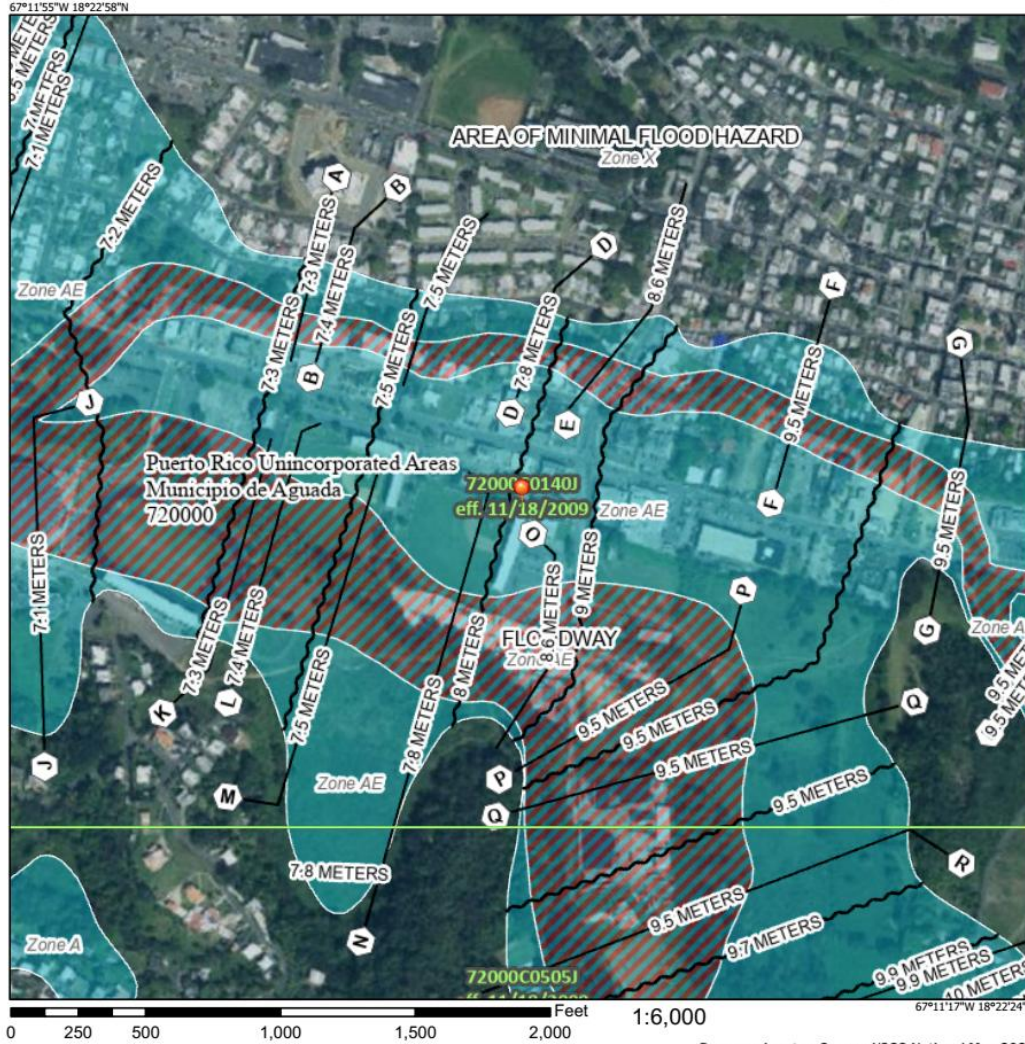
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards.

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 8/21/2026 at 11:59 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Figure 18. Urban Guayabo River Floodplain

National Flood Hazard Layer FIRMette



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) Zone A, V, A99 With BFE or Depth Zone AE, AO, AH, VE, AR Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X Future Conditions 1% Annual Chance Flood Hazard Zone X Area with Reduced Flood Risk due to Levee. See Notes. Zone X Area with Flood Risk due to Levee Zone D
OTHER AREAS	NO SCREEN Area of Minimal Flood Hazard Zone X Effective LOMRs Area of Undetermined Flood Hazard Zone D
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer Levee, Dike, or Floodwall
OTHER FEATURES	Cross Sections with 1% Annual Chance Water Surface Elevation Coastal Transect Base Flood Elevation Line (BFE) Limit of Study Jurisdiction Boundary Coastal Transect Baseline Profile Baseline Hydrographic Feature
MAP PANELS	Digital Data Available No Digital Data Available Unmapped The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

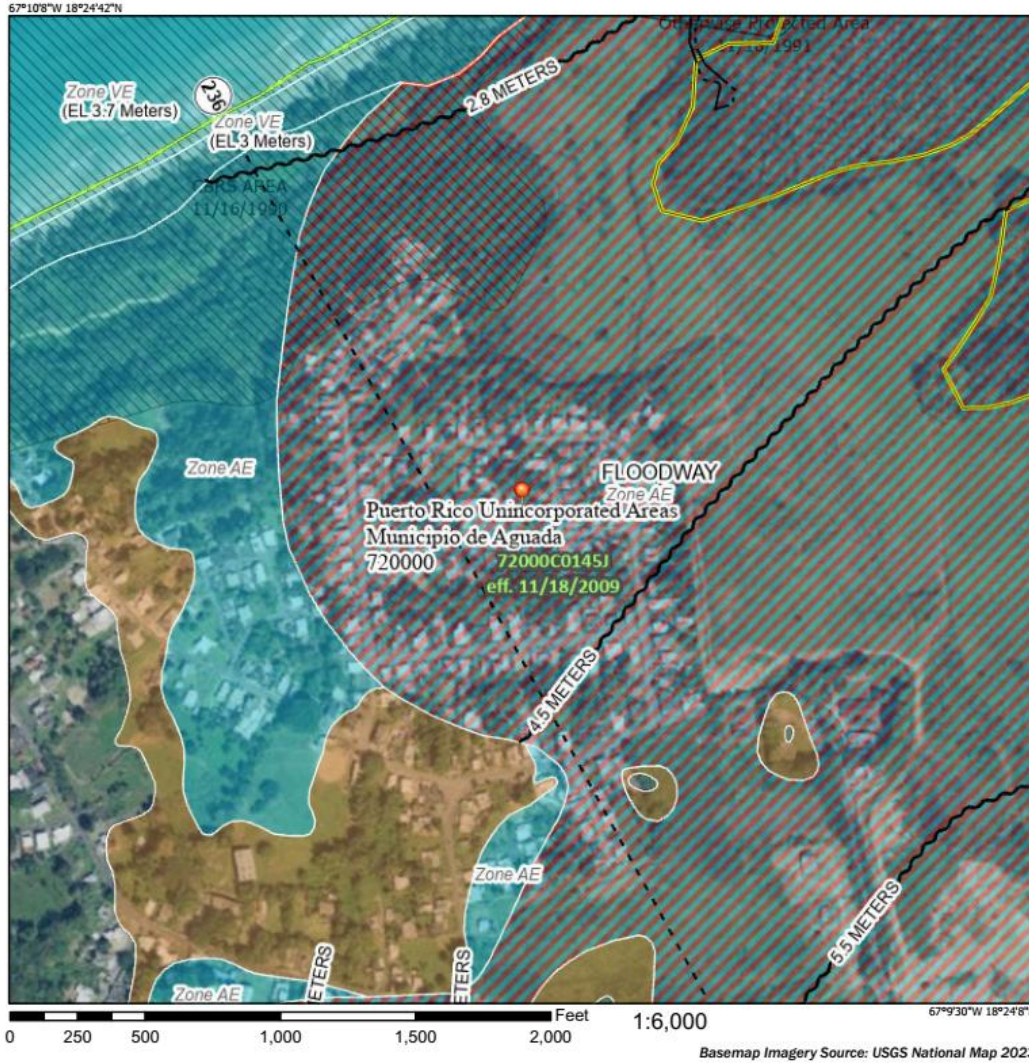
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 8/21/2026 at 3:49 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Figure 19. Culebrinas River and Caño Madre Vieja Floodplain

National Flood Hazard Layer FIRMedette



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) Zone A, X, A99
	With BFE or Depth Zone AE, AO, AH, VE, AR
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
	Future Conditions 1% Annual Chance Flood Hazard Zone X
	Area with Reduced Flood Risk due to Levee. See Notes, Zone X
	Area with Flood Risk due to Levee Zone D
OTHER AREAS	NO SCREEN Area of Minimal Flood Hazard Zone X
	Effective LOMRs
GENERAL STRUCTURES	Area of Undetermined Flood Hazard Zone D
	Channel, Culvert, or Storm Sewer
OTHER FEATURES	Levee, Dike, or Floodwall
	Cross Sections with 1% Annual Chance Water Surface Elevation
MAP PANELS	Coastal Transect
	Base Flood Elevation Line (BFE)
	Limit of Study
	Jurisdiction Boundary
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
	Digital Data Available
	No Digital Data Available
	Unmapped

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards.

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 8/21/2026 at 3:08 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

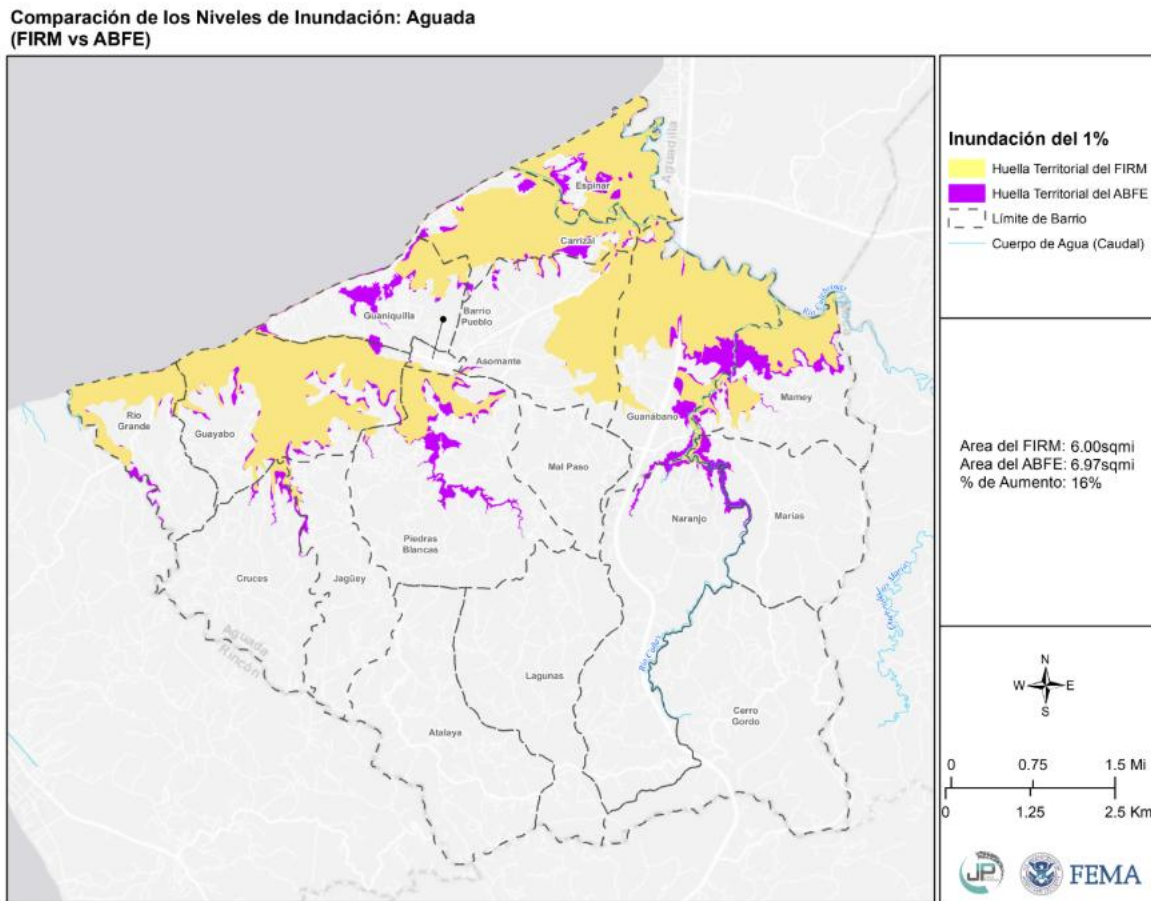
Advisory Base Flood Elevation (ABFE)

Likewise, FEMA uses another type of map for the purpose of developing regulations and construction permits known as the Advisory Base Flood Elevation Maps (ABFE). ABFEs are developed after the occurrence of a high-impact atmospheric event, and several factors related to the latest engineering analysis are taken into consideration to determine whether an analysis is necessary. Some of the factors considered in the analysis include the age of the analysis, the territory covered by the analysis, and the engineering models/data used in the analysis. ABFEs have been produced for states such as Mississippi (Hurricane Katrina), New York, and New Jersey (Hurricane Sandy). Following Hurricane María's passage through Puerto Rico in 2017, and due to the availability of better data, FEMA developed ABFEs for Puerto Rico. It should be noted that the Puerto Rico Planning Board adopted the ABFEs on an emergency basis in March 2018. At present, Puerto Rico has two (2) types of flood maps: the FIRMs (2009), which are used solely for flood insurance rates, and the ABFEs (2018), which are used to regulate construction on the Island.

For comparison purposes, this subsection includes the difference in the extent of land affected by flooding based on the FIRMs prior to Hurricane María in September 2017 and the ABFEs developed by FEMA for Puerto Rico. After Hurricane María in 2017, the areas designated as flood-prone throughout the Island increased by 20%. Thus, this reflected an increase of 41%.

The next figure (in Spanish) illustrates the difference between the floodplain extent depicted in the pre-Hurricane María Flood Insurance Rate Maps (FIRMs) and the Advisory Base Flood Elevation (ABFE) maps developed after the hurricane for the 1% annual chance flood event (100-year flood). In the Municipality of Aguada, the ABFE mapping reflects an increase of approximately 16% in flood-prone areas, from 6.00 square miles to 6.97 square miles. This increase indicates that areas exposed to flooding are more extensive than previously identified and exceed those reflected in the municipality's previous Hazard Mitigation Plan. The newly identified flood-prone areas include expansions of existing flood zones, as well as additional areas along the Grande River from Añasco, the Culebrinas River, and several tributary streams throughout the municipality, particularly in the neighborhoods of Guanábano, Naranjo, Carrizal, and Espinar. These changes are especially evident along inland drainage corridors and portions of the coastal plain, highlighting an increased potential for flood impacts in areas not previously identified as being at risk.

Figure 20. ABFE vs FIRM 1% (100 years)



As instructed by PRPB the hazard analysis was made using the ABFE maps.

HAZUS Modeling

Flooding source identification and hazard loss estimation were performed using Federal Emergency Management Agency's (FEMA) Hazus platform, a nationally standardized tool for multi-hazard risk assessment. The Hazus flood module was used to delineate streams in areas where no engineering studies have been developed and also used to estimate potential monetary losses associated with structural damage.

Input data included depth grids produced by a Base Level Engineering (BLE) study in 2018 post hurricanes Irma and Maria. This BLE study did not review all potential riverine flooding sources so additional modeling was developed with Hazus hydrology and hydraulics to review other potential losses associated with streams with drainage

areas of one square mile or more.

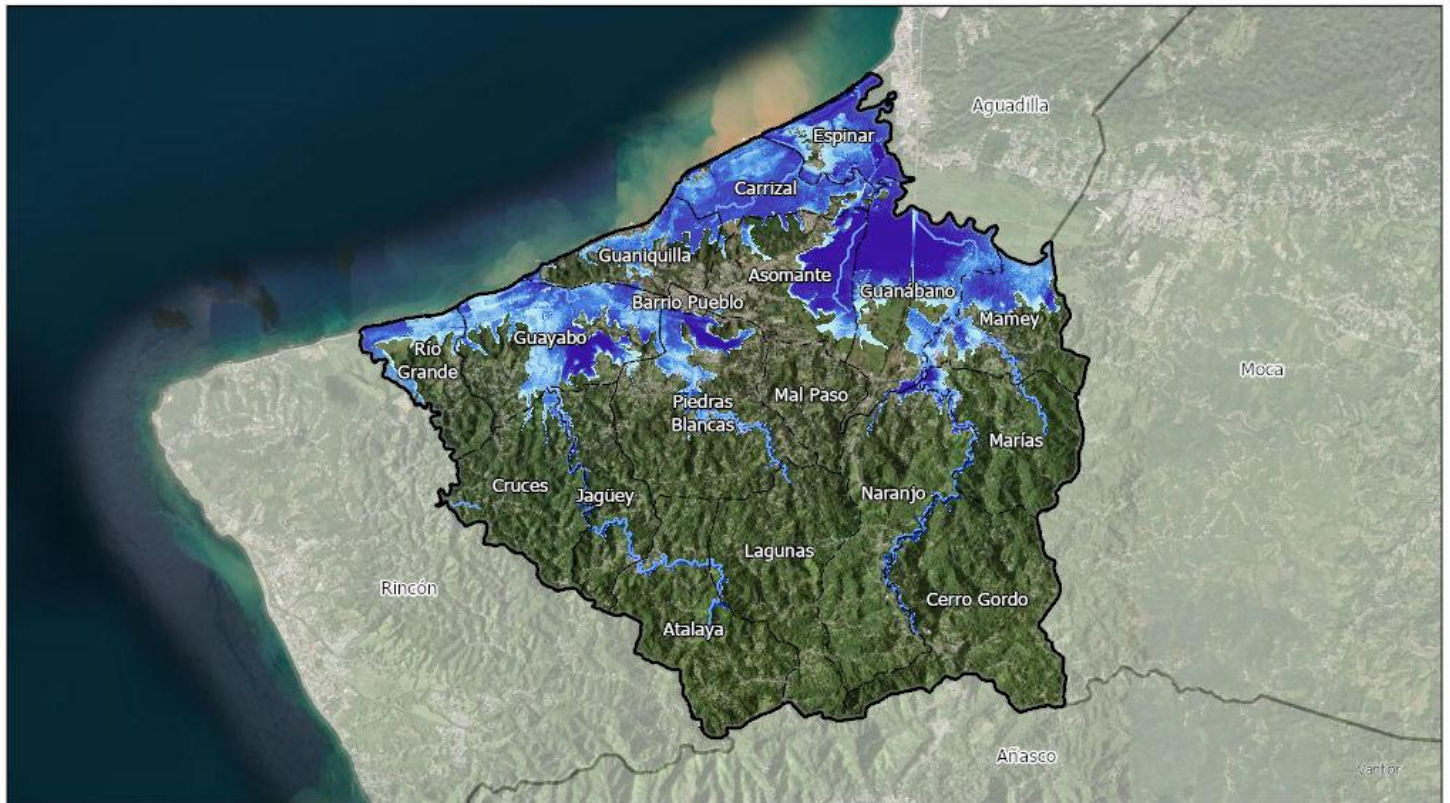
Topographic data used by Hazus for depth calculations and damage estimation was sourced from the USGS 3D Elevation Program (3DEP) seamless 1/3 arc-second Digital Elevation Model (DEM), at an approximate resolution of 10 feet. This dataset provides current coverage of Puerto Rico and its surrounding islands.

The 3DEP seamless DEM for Puerto Rico is derived from two lidar collection efforts: a 2016–2017 USGS lidar survey and a 2018 USGS post-Hurricane Maria lidar survey. The 2018 collection, conducted following the significant coastal geomorphic changes caused by Hurricane Maria, represents the most current available terrain data for the island and forms the primary basis of the 3DEP elevation layer used in this analysis.

The areas documented in the maps included within the LHMP may have streamlines represented but with no depth grids associated with them. Due to the inconsistency of available regression equations and other data necessary for computation of flood risk and losses with Hazus's hydrology and hydraulics models, some streams that were delineated were unable to be completed during modeling runs. These stream areas may need to be reviewed for future flood studies and potential flood risk identification but, due to the lack of data, they were unable to be included in the Hazus studies.

The following map shows the results of the Hazus flood modeling for the 500-year flood event. The most up-to-date Hazus analysis indicates that flood impacts may extend beyond the areas identified in the ABFE mapping, particularly along major drainage corridors and low-lying coastal areas. The greatest flood depths are concentrated in the northern portion of the municipality, including portions of the neighborhoods of Espinar, Carrizal, Guanábano, and Guaniquilla, as well as along sections of the Grande River from Añasco and other tributary streams. Additional flood-prone areas are also identified along inland drainage networks extending through Naranjo, Marías, and surrounding wards. These results highlight the potential for extensive flood impacts during extreme flood events and provide a more comprehensive assessment of areas that may be exposed to future flood risk.

HAZUS ANALYSIS FOR 500-YEAR FLOOD EVENT



Source: Puerto Rico Planning Board and Hazus 6.1 Output

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4.9.1.2 Risk Magnitude (B1-c)

Flood events can represent one of the most severe atmospheric threats, as there is no other event worldwide that causes greater loss of life (FEMA, 1997). This is due to the high frequency of such events and the population's lack of awareness regarding the magnitude of the damage they can cause, whether physical harm or property damage. It should be noted that most disaster declarations in the U.S. are related to flood events. The majority of flood-related incidents involve people being swept away by fast-moving water, along with their vehicles (FEMA, 1997). Each year, the devastation caused by floods results in billions of dollars in asset losses. Highly urbanized areas with dense populations are particularly vulnerable to flash floods, as the construction of buildings, roads, and parking lots create impermeable surfaces, reducing the land's natural ability to absorb water (NSWL, n.d.).

Floods are the most common natural disaster, occurring when water overflows and submerges land that is typically dry. They are often triggered by heavy rainfall, rapid snowmelt, or storm surges from tropical cyclones or tsunamis in coastal regions. Floods can cause extensive destruction, including loss of life and severe damage to homes, property, and critical public health infrastructure. Between 1998 and 2017, floods impacted more than 2 billion people worldwide. Those living in floodplains, in poorly constructed buildings, or without access to warning systems and hazard awareness are the most vulnerable (WHO, 2025).

Three common types of floods include:

- Flash floods: Result from sudden, intense rainfall that rapidly raises water levels, overwhelming rivers, streams, channels, or roads.
- River floods: Occur when prolonged rainfall or snowmelt causes rivers to exceed their capacity.
- Coastal floods: Caused by storm surges linked to tropical cyclones or tsunamis.

Regarding the impact on life, property, and operations, floods cause loss of life and property damage, including residences, buildings, infrastructure, agriculture, and sanitation and drainage systems. After a flooding event, the aftermath can increase the occurrence of various diseases, such as leptospirosis, and lead to rises in contaminated water (Malilay, 2000).

According to a Congressional Budget Office (CBO) report, "Over the past 10 years, damage from flooding in the United States has averaged \$46 billion per year (in 2023

dollars)” (CBO, 2024). This estimate includes costs such as:

- The replacement of residential and commercial property;
- Repairs for or rebuilding of public infrastructure;
- Emergency response measures;
- Costs associated with the continued loss of property use (for example, the provision of temporary housing);
- Commercial losses resulting from business interruptions; and
- Damage to crops, livestock, and timber” (CBO, 2024).

Although the effectiveness of adaptation projects varies, estimates by the U.S. Army Corps of Engineers indicate that approximately two-thirds of its projects—excluding those in the highest and lowest sixth of benefit–cost ratios—are expected to reduce flood damages by \$2 to \$6 for every dollar invested over a 50-year project lifespan (CBO, 2024).

4.9.1.3 Past Events (B1-d)

For the most part, flooding events in Puerto Rico are related to tropical systems (tropical waves, tropical depressions, tropical storms and hurricanes). Consequently, flooding hazards occur most frequently during Atlantic hurricane season, which extends from June 1 through November 30.

However, flooding events can occur outside this window as shown in the case of the April– May 2024 Floods, the February 2022 floods and the Three Kings’ Flooding of 1992. The following table summarizes the major flooding events in the period of 2010 – 2025

Table 28. Major flooding events in Puerto Rico 2010–2025

Event	Date	Disaster Declaration Number	Aguada Included?	Description
Tropical Storm Ernesto	8/14/2024 – 8/16/2024	DR-4850- PR	Public Assistance: No Individual Assistance: No	The storm’s slow movement and moisture-rich environment contributed to prolonged precipitation, particularly in central and eastern municipalities. Parts of Central Puerto Rico recorded 12–14 inches of rainfall in localized areas.
Puerto Rico Severe Storms, Flooding, Landslides, and Mudslides	4/29/2024 – 5/10/2024	DR-4805-PR	Public Assistance: No Individual Assistance: No	In April 2024, Puerto Rico was struck by a series of severe storms that delivered prolonged heavy rainfall—some areas received more than 10 inches—leading to widespread flooding and landslides. Central and western municipalities saw rivers overflow, with the Manatí and Cibuco rivers breaching their banks and inundating highways like PR-2. Urban areas, especially in the southwest (Cabo Rojo, Mayagüez, Ponce), faced flash flood warnings as heavy afternoon downpours overwhelmed drainage systems. Floodwater turned streets into torrents, trapping residents on rooftops and prompting emergency evacuations in over 20 municipalities.
Hurricane Fiona	9/17/2022 – 9/21/2022	DR-4671-PR	Public Assistance: Yes Individual Assistance: Yes	Hurricane Fiona struck Puerto Rico in September 2022, unleashing torrential rains—up to 31.22 inches of rainfall over 72 hours in Ponce, nearly matching the accumulation from Hurricane

Event	Date	Disaster Declaration Number	Aguada Included?	Description
				Maria. This deluge led to catastrophic flooding, with 7 to 20 inches common across most of the island and localized spots exceeding 30 inches.
Puerto Rico Severe Storm, Flooding and Landslide	2/4/2022 – 2/6/2022	DR-4649-PR	Public Assistance: No Individual Assistance: No	In February 2022, Puerto Rico experienced a severe storm that brought prolonged heavy rainfall, causing widespread flooding across the island. Rainfall totals ranged from 3 to 10 inches in many areas, with localized peaks reaching up to 16 inches in Toa Alta. The intense precipitation overwhelmed drainage systems, leading to urban flooding in San Juan, Guaynabo, and coastal towns such as Dorado and Vega Baja. Rivers swelled beyond their banks, inundating roads and isolating communities, while landslides compounded the damage in mountainous regions. Emergency responders issued flash flood warnings and conducted evacuations as homes and businesses were submerged.
Puerto Rico Severe Storm and Flooding	9/13/2020	DR-4571-PR	Public Assistance: No Individual Assistance: No	Puerto Rico was battered by a severe storm and flooding on September 13, 2020, resulting in widespread flood damage and infrastructure disruption. Torrential rains overwhelmed drainage systems and caused rivers to overtop in areas like Arecibo, where one home was destroyed, over 100 suffered major damage, and more than 20 experienced minor flooding. Roads and bridges were submerged or damaged, isolating

Event	Date	Disaster Declaration Number	Aguada Included?	Description
				communities and impeding emergency response efforts. Floodwaters inundated homes and public facilities, prompting evacuation orders and flash flood warnings across several municipalities.
Tropical Storm Isaías	7/29/2020 - 7/30/2020	DR-4560-PR	Public Assistance: No Individual Assistance: Yes	Although the center of Tropical Storm Isaías did not make landfall on the island, the system left a large amount of rain in its path, causing flooding throughout Puerto Rico. Rainfall accumulation of up to 10 inches was recorded around the island.
Hurricane María	9/20/2017	DR-4339-PR	Public Assistance: Yes Individual Assistance: Yes	Hurricane Maria produced some of the most severe flooding ever experienced in Aguada. Intense and prolonged rainfall caused rivers and streams to overflow, inundating residential areas, roadways, and low-lying communities throughout the municipality. Floodwaters disrupted transportation, isolated neighborhoods, and damaged public infrastructure, while saturated soils increased runoff and contributed to additional hazards in vulnerable areas. The event highlighted Aguada's susceptibility to both riverine and urban flooding, demonstrating how extreme precipitation associated with major hurricanes can generate widespread impacts well beyond the immediate coastal zone.
Hurricane Irma	9/5/2017	DR-4336-PR	Public Assistance: No Individual Assistance: No	On September 5, 2017, Hurricane Irma impacted Puerto Rico; an Emergency Declaration was issued for the Island. On September 6, 2017, a Major Disaster Declaration was issued following

Event	Date	Disaster Declaration Number	Aguada Included?	Description
				Hurricane Irma's passage. Two people died due to torrential rains before the hurricane: a man died in Orocovis after falling from his ladder while repairing his roof; another man on the coast in Capitanejo died after being struck by lightning. Wave heights in Puerto Rico reached 9 meters, and sustained winds of 111 mph were recorded in Culebra.
Tropical Storm María ⁹	9/8/2011 – 9/14/2011	DR-4040-PR	Public Assistance: No Individual Assistance: No	Tropical Storm Maria (2011) produced heavy rainfall across Puerto Rico, causing flooding, road closures, and damage to homes and infrastructure in several municipalities, particularly in the eastern region of the Island. Although the most significant impacts were reported outside Aguada, the event demonstrated the capacity of tropical systems to generate widespread flooding and highlighted the vulnerability of Puerto Rico's municipalities to riverine, coastal, and urban flood hazards.
Hurricane Irene	8/22/2011	DR-4017-PR	Public Assistance: Yes Individual Assistance: No	Total rainfall reached 22 inches over three days, with the eastern region being the most affected—the same area that had already received over 6 inches earlier in August during the close passage of Tropical Storm Emily. Flooding was severe enough to cause infrastructure stress and

⁹ Tropical Storm María was a tropical system that pass to the northeast of Puerto Rico in 2011 and that caused flooding in the Island. Not to be confused with the 2017 Hurricane María. The name "María" was retired from the official Atlantic hurricane season list of names after 2017.

Event	Date	Disaster Declaration Number	Aguada Included?	Description
				dangerous conditions across multiple municipalities. Tragically, there was one direct fatality attributed to Irene, due to drowning. Although the eastern region of Puerto Rico experienced the highest rainfall accumulations, flood impacts were reported across multiple regions of the island, highlighting the vulnerability of communities such as Aguada to riverine and urban flooding during major tropical cyclone events.
Puerto Rico Severe Storms, Flooding. Mudslides and Landslides	5/20/2021 – 6/8/2021	DR-4004-PR	Public Assistance: No Individual Assistance: No	In May 2021, Puerto Rico experienced a series of intense rainfall events that caused flash flooding, river overflows, mudslides, and landslides, particularly in mountainous and interior regions. Although May is normally one of the wettest months of the year, several storm systems produced short-duration but high-intensity rainfall, overwhelming local drainage systems and destabilizing steep terrain.
Sub-Tropical Storm Otto	10/3/2010 – 10/8/2010	DR-1946-PR	Public Assistance: No Individual Assistance No	An extensive rain band covered Puerto Rico while Otto moved as a distant tropical cyclone north of the Island (NOAA). This resulted in heavy and continuous rainfall that caused serious flooding. (Eco Exploratorio).
Puerto Rico Severe Storms and Flooding	5/26/2010 – 5/31/2010	DR-1919-PR	Public Assistance: No Individual Assistance: No	In May 2010, Puerto Rico was hit by a series of severe storms that produced torrential rainfall and widespread flooding across the island. Rainfall exceeded 12 inches in some areas,

Event	Date	Disaster Declaration Number	Aguada Included?	Description
				overwhelming drainage systems and causing rivers to overflow their banks. Low-lying communities and urban centers experienced significant inundation, with roads submerged and bridges damaged, isolating several municipalities. Flash floods swept through residential areas, forcing evacuations and leaving homes and businesses underwater. Landslides triggered by saturated soil compounded the crisis, blocking access routes and delaying emergency response efforts. The event resulted in extensive infrastructure damage and highlighted the island's vulnerability to prolonged heavy rain events during the wet season.

In summary, between 2010 and 2025 there were a total of 13 major disaster declarations caused by flooding or events that had flood related damage. Of those, the municipality of Aguada was declared eligible for either Public Assistance or Individual Assistance in four instances. These flood-related disaster declarations resulted in damage to homes, businesses, public infrastructure, and utility systems within the municipality. Flooding disrupted transportation, affected essential services, and required recovery assistance, demonstrating Aguada's continued vulnerability to flood hazards.

4.9.1.4 Special Consideration: Floods by Stormwater Management Deficiencies

Urban drainage systems – whether natural or constructed – are designed to convey surface water runoff to receive water bodies. When storm drains, channels, or swales become obstructed, insufficient or overwhelmed by heavy rainfall and expanding urbanization, they can overflow and flood surrounding areas. As a result, floodwaters may spread beyond FEMA's mapped floodplains, even entering zones typically considered low or moderate risk (e.g., Zones B, C, or X) (FEMA, Reducing Damage from Localized Flooding, 2025).

Puerto Rico's stormwater runoff is conditioned by the island's climate, topography and land cover. Annual rainfall varies from less than 1,000 millimeters (mm) to over 4,000 mm (40 to 157 inches). The island's watersheds are largely mountainous, with steep slopes, and stream valleys are typically narrow and well-incised. Intense but short-duration storms are common, leading to rapid flooding with peak discharges that can be several orders of magnitude higher than base flows. All of Puerto Rico's watersheds have experienced significant alterations. It is estimated that more than 11% of the island is covered by developed surfaces, within areas reaching up to 40% in regions such as the San Juan Metropolitan Area. These changes have significantly modified stormwater drainage patterns and downstream floodwater levels (FEMA, 2024).

Paved surfaces severely limit the infiltration of rainwater, increasing both the volume and velocity of surface runoff. As a result, storm drains can easily become overwhelmed. In addition, runoff from paved surfaces reaches streams and rivers much faster, exceeding their capacity to convey water and causing higher and more frequent flood levels in adjacent areas. Moreover, contaminants from both point and non-point pollution sources are more likely to reach surface water bodies when transported by runoff over paved surfaces instead of being partially or totally degraded by vegetated soils. Higher flows also have a greater capacity to remove and transport soil and other loose materials from streambanks and riverbeds, facilitating

erosion and scouring (FEMA, 2024).

Paradoxically, river flow between rain events tend to decrease after urbanization. Paved surfaces act as a barrier that isolates the soil, preventing the infiltration of rainwater that otherwise would have gradually discharged from the ground and into streams days later, a process that is critical for maintaining base flows for riparian fish and wildlife species, but also to sustain public water supply. In response, various hard infrastructure measures (hard infrastructure measures such as flood-control pump stations, concrete trapezoidal channels, and curved side gutters have been widely implemented across Puerto Rico. While effective at quickly conveying runoff, these structures often neglect ecological, social, cultural, and aesthetic considerations. These practices often involve significant operation and maintenance costs and, in many instances, can exacerbate downstream erosion, scouring and water quality problems.

A more sustainable approach would be to take advantage of the ecological services that green areas and other nature-based solutions to manage runoff flows and improve water quality. Such strategies are increasingly critical to protect communities from the growing water-related impacts of climate change in Puerto Rico (FEMA, 2024).

4.9.1.5 Future Event Probabilities (B1-e)

A sustained increase in the frequency of extreme rainfall events has been identified in recent decades. As stated above, the Island of Puerto Rico has had 13 flood – related flood major disaster declaration in the last fifteen years. This means that the average frequency of a flooding event is approximately every 14 months.

Any mitigation action adopted to reduce the effects of flooding in the Municipality of Aguada must consider, for example, that 100-year return events or those with a 1% annual probability could become 50-year return events or have a 2% annual probability in the future. This means that flood events of a certain magnitude and impact on the municipality may increase, particularly in high-risk areas. Though there are many floods control projects in Aguada, the probability of future events is considered high.

4.9.2 Risk Analysis (B2-a, B2-b)

4.9.2.1 Estimated Losses

The FEMA National Risk Index (NRI) provides estimates of flood exposure and expected annual losses for the municipality. Exposure represents the value of buildings, population, and other assets located within areas susceptible to flooding. Table 29 summarizes the municipality's exposure to flood hazards.

The FEMA NRI analysis indicates that approximately 1.52 square miles of Aguada are located within areas exposed to flooding. Within these areas, the estimated exposed building value exceeds \$677 million, while approximately 4,298 residents are located within the flood-prone area. Overall, the municipality's total exposure is estimated at more than \$50.5 billion, reflecting the combined value of exposed buildings, population, and population-equivalent assets. These findings demonstrate that flooding poses a significant risk to developed areas of the municipality and has the potential to affect residential neighborhoods, businesses, transportation infrastructure, and critical facilities.

The expected annual loss (EAL) represents the average annualized economic impact anticipated from flood events over time. As shown in Table 30, the FEMA NRI estimates an annual flood-related building loss of approximately \$9.46 million, accounting for most of the municipality's flood risk. When population-related impacts are considered, the total expected annual loss is estimated at approximately \$10.03 million. These results indicate that flooding remains one of the most significant natural hazards affecting Aguada and underscore the importance of continued investments in floodplain management, drainage improvements, resilient construction practices, and other mitigation measures aimed at reducing future losses.

Table 29. Flood Exposure

Exposure - Impacted Area (sq mi)	Exposure - Building Value	Exposure - Population	Exposure - Population Equivalence	Exposure - Total
1.515393	\$ 677,222,991	\$ 4,298	\$ 49,858,992,663	\$ 50,536,215,654

Source: FEMA NRI

Table 30 presents the estimated annual losses associated with flooding in Aguada, as reported by the FEMA National Risk Index.

Table 30. Expected Annual Loss to Flood

Expected Annual Loss - Building Value	Expected Annual Loss - Population	Expected Annual Loss - Population Equivalence	Expected Annual Loss -Total
\$9,459,493	0.048906	\$567,296	\$10,026,789

Source: FEMA NRI

Maps 35 and 36 illustrate the estimated building losses associated with 100-year and 500-year flood events in Aguada based on Hazus 6.1 modeling results. In both scenarios, the highest projected losses are concentrated in the northern portion of the municipality, particularly within census tracts located in and around the wards of Grande River, Guayabo, Guaniquilla, Carrizal, and Espinar. These areas contain the largest concentrations of structures exposed to flood hazards and account for the municipality's greatest potential economic losses.

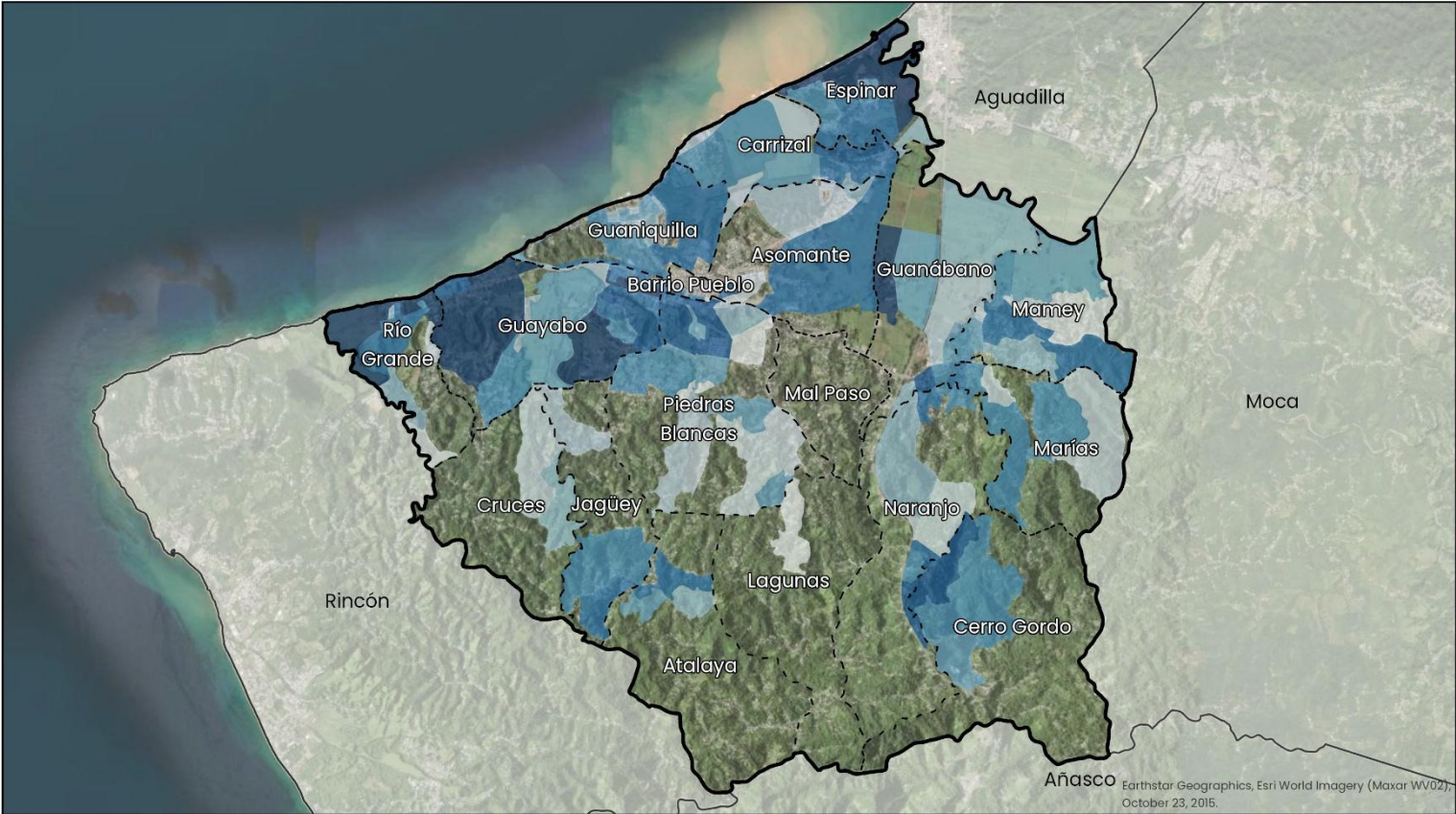
Under the 100-year flood scenario (Map 35), estimated building losses range from less than \$10,000 to approximately \$8.96 million per census tract. Under the 500-year flood scenario (Map 36), losses increase and reach approximately \$10.64 million in the most affected census tracts. While the overall spatial distribution of losses remains similar between the two scenarios, the 500-year event produces greater damage due to the increased magnitude and extent of flooding.

The maps indicate that flood-related economic risk is not evenly distributed throughout Aguada. Rather, the highest concentrations of potential losses occur in developed areas where significant building inventory coincides with flood-prone locations. These findings highlight the importance of floodplain management, resilient construction practices, drainage improvements, and other mitigation measures in areas with the greatest exposure to future flood losses.

As a reminder this map does not measure extent of flood, but rather the possible loss by flooding. In this northern section there are various rivers that can overtop bridges of affect nearby structures.

Map 35. Building Loss to Flood Exposure 500-year flood

BUILDING LOSS TO FLOOD EXPOSURE 500-YEAR FLOOD

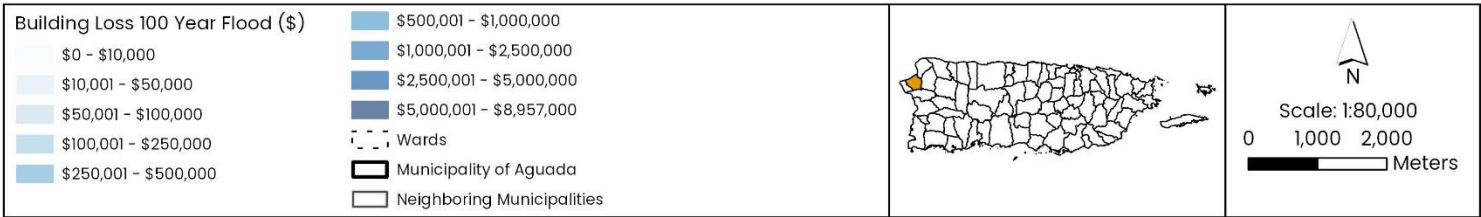
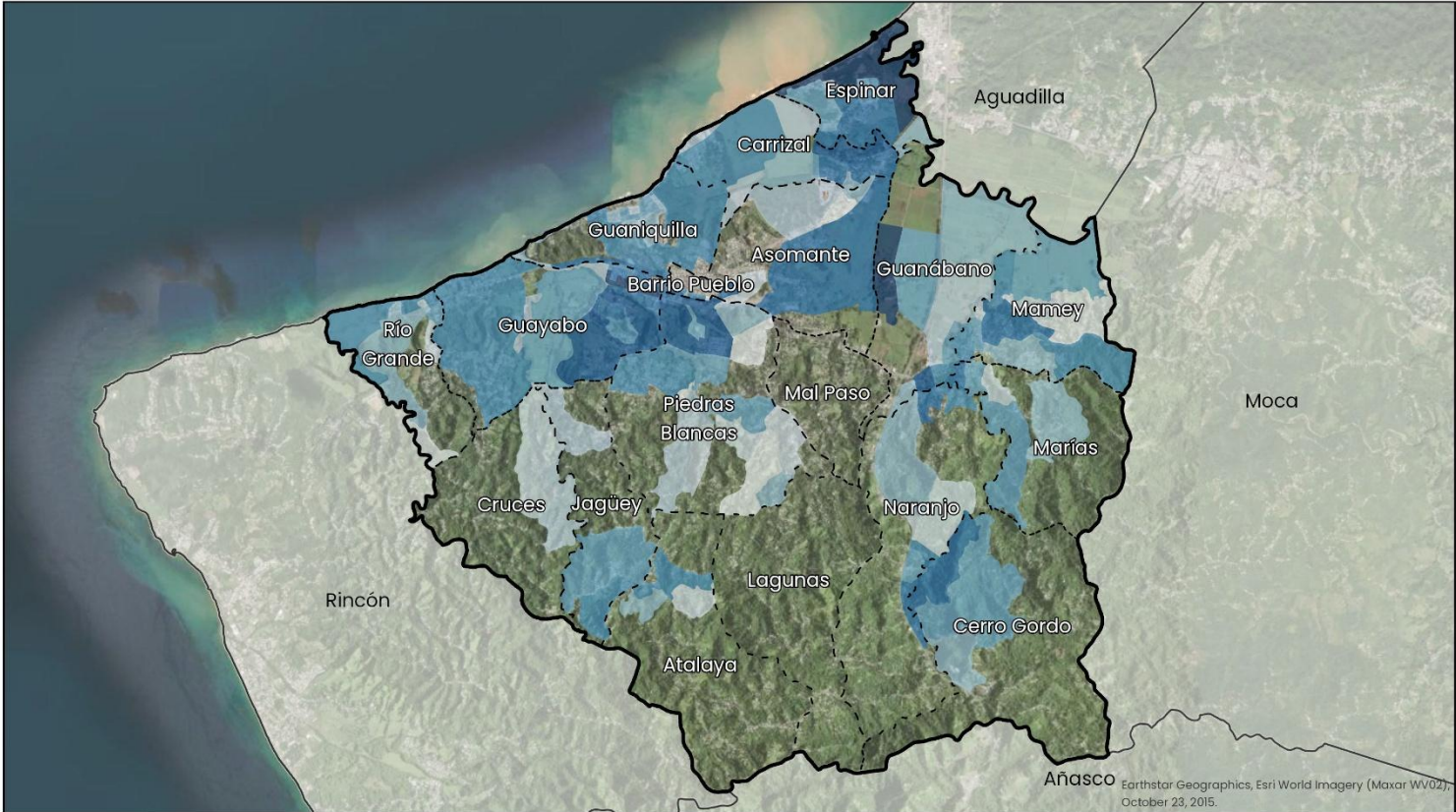


Source: Puerto Rico Planning Board, Hazus 6.1 Output and Census Block

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BUILDING LOSS TO FLOOD EXPOSURE 100-YEAR FLOOD



After running the Hazus model, the following losses were determined for flooding in Aguada:

- A total of 19,650 structures are identified within the study area, including 19,560 residential structures and 90 non-residential structures (see Table 31).
- An estimated total of \$117,382,000 in losses is projected for a 100-year flood event (1% annual chance) and \$182,251,000 for a 500-year flood event (0.2% annual chance) (see Table 32).
- Specifically, for non-residential structures, total losses are estimated at \$8,020,000 for the 100-year event and \$9,019,000 for the 500-year event (see Table 32).
- For residential structures, losses are estimated at \$109,362,000 for the 100-year event and \$173,232,000 for the 500-year event, accounting for the vast majority of the projected flood-related damages (see Table 32).
- Non-residential losses are concentrated in commercial and educational occupancies, which account for most of the projected losses under both flood scenarios (see Table 33).
- Detailed residential losses indicate that structural damage represents the largest component of losses, increasing from approximately \$39.3 million during the 100-year event to approximately \$103.2 million during the 500-year event. Additional losses are associated with building contents, relocation expenses, and rental income impacts (see Table 34).

Table 31. Total Structures at Risk

Structures	
Non-Residential	90
Residential	19,560
Total	19,650

Table 32. Aggregated Loss of dollars for 1% (100-year) and 0.2% (500-year) events

Occupancy Type	Losses in Dollars. 1% Event	Losses in Dollars. 0.2% Event
Non-Residential	\$8,020,000	\$9,019,000
Residential	\$109,362,000	\$173,232,000
Total	\$117,382,000	\$182,251,000

Table 33. Detailed Loss for Non-Residential Buildings

Occupancy	Losses in Dollars, 1% Event	Losses in Dollars, 0.2% Event
Commercial	\$4,791,000	\$4,823,000
Education	\$2,951,000	\$3,918,000
Government	\$0	\$0
Religious	\$0	\$0
Agriculture	\$0	\$0
Industrial	\$278,000	\$278,000
Total	\$8,020,000	\$9,019,000

Table 34. Detailed Loss for Residential Buildings

Residential, Detailed Losses	Losses in Dollars, 1% Event	Losses in Dollars, 0.2% Event
Structure	\$39,316,000	\$103,192,000
Contents	\$21,769,000	\$39,339,000
Relocation	\$31,050	\$10,643,050
Rental Income	\$17,227,000	\$22,180,000
Total	\$78,343,050	\$175,354,050

The Hazus results demonstrate that flooding represents a significant risk to Aguada, with potential losses exceeding \$117 million during a 100-year flood event and \$182 million during a 500-year flood event. Residential structures account for most of the projected damage, underscoring the need for continued mitigation efforts aimed at reducing flood vulnerability and protecting life and property throughout the municipality.

4.9.2.2 Lifelines and Critical Infrastructure

Flooding is among the most disruptive natural hazards, affecting all eight FEMA Community Lifelines. These lifelines represent essential services that support public health, safety, and economic stability. Below is an analysis of some of the impacts that flooding can have on lifelines:

- **Safety and Security** – Flooding can damage emergency services infrastructure such as police stations, fire departments, and emergency operations centers. Blocked evacuation routes and submerged roads hinder rescue efforts, while prolonged outages increase vulnerability to crime and civil unrest.
- **Food, Water, Shelter** – Floodwaters can contaminate drinking water supplies and damage water treatment facilities. Food supply chains may be severely disrupted when warehouses and grocery stores are flooded. Damage to residential structures can result in displacement, creating urgent demand for temporary shelters.
- **Health and Medical** – Hospitals and clinics may become inaccessible or experience power outages during flood events. Flood conditions can contribute to increased incidence of waterborne diseases and mold-related illnesses increase significantly. Disruptions to medical supply chains may delay both emergency care and routine treatments.
- **Energy (Power and Fuel)** – Flooding can submerge electrical substations and transformers, causing widespread outages. Fuel distribution networks may be disrupted due to impassable roads and damaged transportation routes. Prolonged power loss can significantly affect critical facilities such as hospitals and water treatment plants.
- **Communications** – Flooding can damage cell towers, fiber-optic cables, and emergency communication systems, reducing the capacity to coordinate rescue and recovery operations. This disruption can delay the dissemination of critical information.
- **Transportation** – Flooding can wash out or undermine roads, bridges, and rail lines, rendering them impassable. Airports and seaports may be forced to suspend operations, delay evacuation and the delivery of emergency supplies. Also, transportation disruptions amplify the overall impact of the disaster.
- **Hazardous Materials** – Floodwaters can mobilize and disperse hazardous substances from industrial sites, sewage systems, and fuel storage tanks, increasing the risk of environmental contamination. Cleanup efforts can become complex, costly and time-consuming, potentially resulting in long-term public and environmental impacts.

- **Water Systems** – Floodwaters can contaminate drinking water supplies and damage water treatment facilities. Excessive inflow from floodwaters may overwhelm sewer systems, causing untreated sewage to backflow into streets and homes. Flood conditions can exceed the design capacity of storm drains and retention basins, resulting in urban flooding and infrastructure damage. The accumulation of sediment and debris clog drainage systems, reducing effectiveness and increasing flood risk during subsequent storms events.

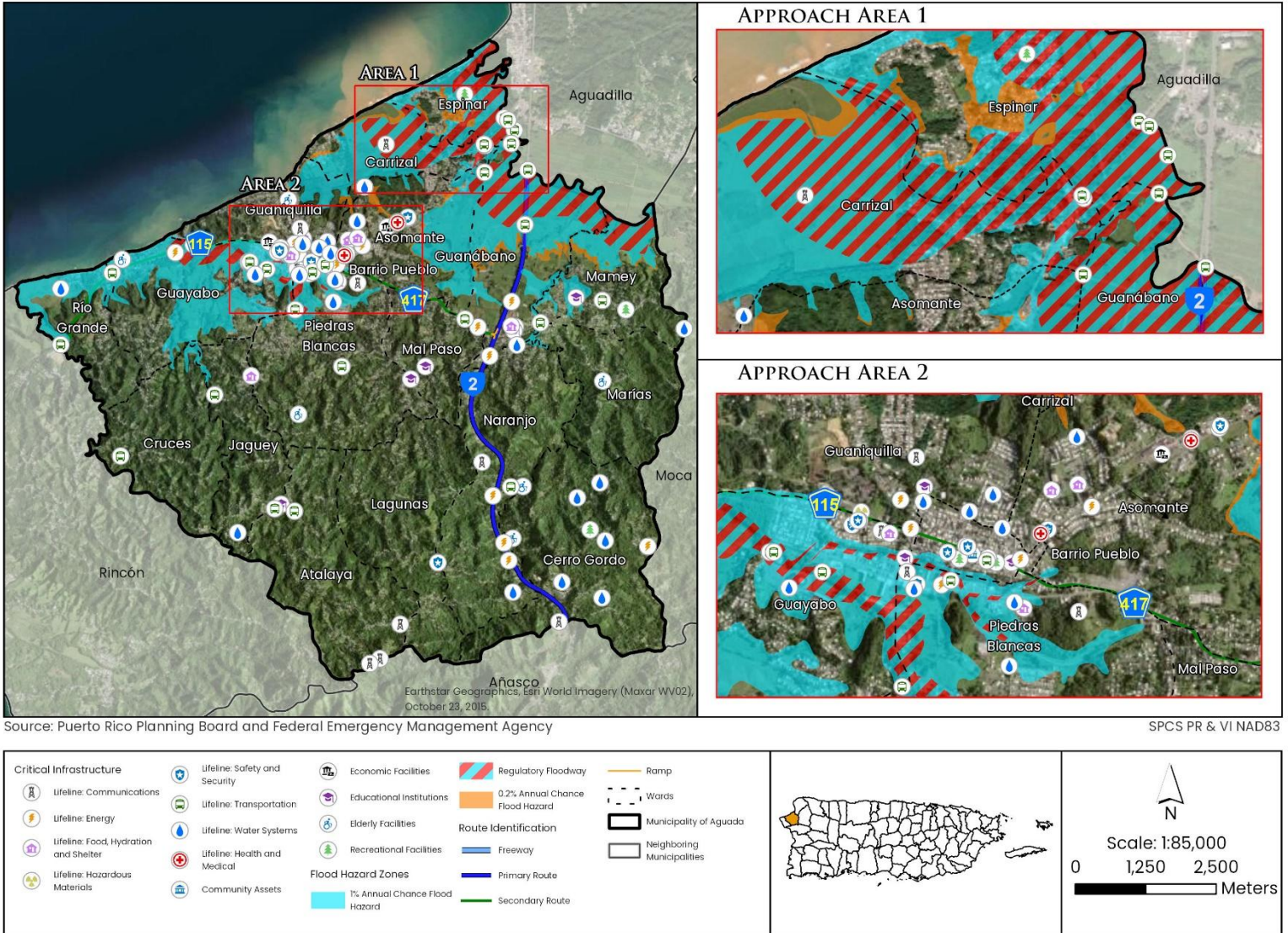
Map 37 illustrates the location of critical infrastructure facilities in relation to FEMA-mapped flood hazard areas within the Municipality of Aguada. The map shows that several critical facilities are located within or adjacent to the 1-percent annual chance flood hazard area (100-year floodplain), the 0.2-percent annual chance flood hazard area (500-year floodplain), and the regulatory floodway.

The highest concentration of potentially exposed critical infrastructure is located in the northern portion of the municipality, particularly within the Guaniquilla, Barrio Pueblo, Asomante, Carrizal, Espinar, and Guanábano sectors. Approach Areas 1 and 2 highlight locations where multiple critical facilities coincide with mapped flood hazard areas.

The mapped facilities include assets associated with several community lifelines, including transportation, water systems, communications, energy, safety and security, health and medical services, educational institutions, community assets, recreational facilities, and elderly care facilities. The map indicates that flood hazard areas overlap portions of the municipality where numerous critical facilities are concentrated, particularly in the northern and urbanized areas of Aguada.

The regulatory floodway is primarily located within portions of the northern coastal area and overlaps several critical facilities identified in Approach Area 1. Additional concentrations of critical infrastructure exposed to mapped flood hazards are present in Approach Area 2, near the Barrio Pueblo, Guaniquilla, Guayabo, and Asomante sectors.

FLOOD: CRITICAL INFRASTRUCTURE EXPOSURE



4.9.2.3 *Social Vulnerabilities*

Social vulnerability to flood hazards is influenced not only by the physical extent of flooding but also by the location and concentration of the population within flood-prone areas. Communities with larger exposed populations are generally more likely to experience disruptions to housing, transportation, access to services, and daily activities during flood events. Higher population concentrations within hazard areas may also increase the demand for emergency response, evacuation assistance, temporary sheltering, and post-disaster recovery resources.

Map 38 illustrates the distribution of the population exposed to flood hazards within Aguada. The highest concentrations of exposed population are located within the northern portion of the municipality, particularly in Carrizal, Espinar, and Guanábano. Moderate levels of exposed population are also present in portions of Guaniquilla, Barrio Pueblo, Asomante, Guayabo, Grande River, and Mamey. In contrast, lower levels of exposed population are observed throughout the southern portion of the municipality. The map indicates that a substantial portion of the municipality's flood-exposed population is concentrated within the northern coastal and near-coastal sectors of Aguada.

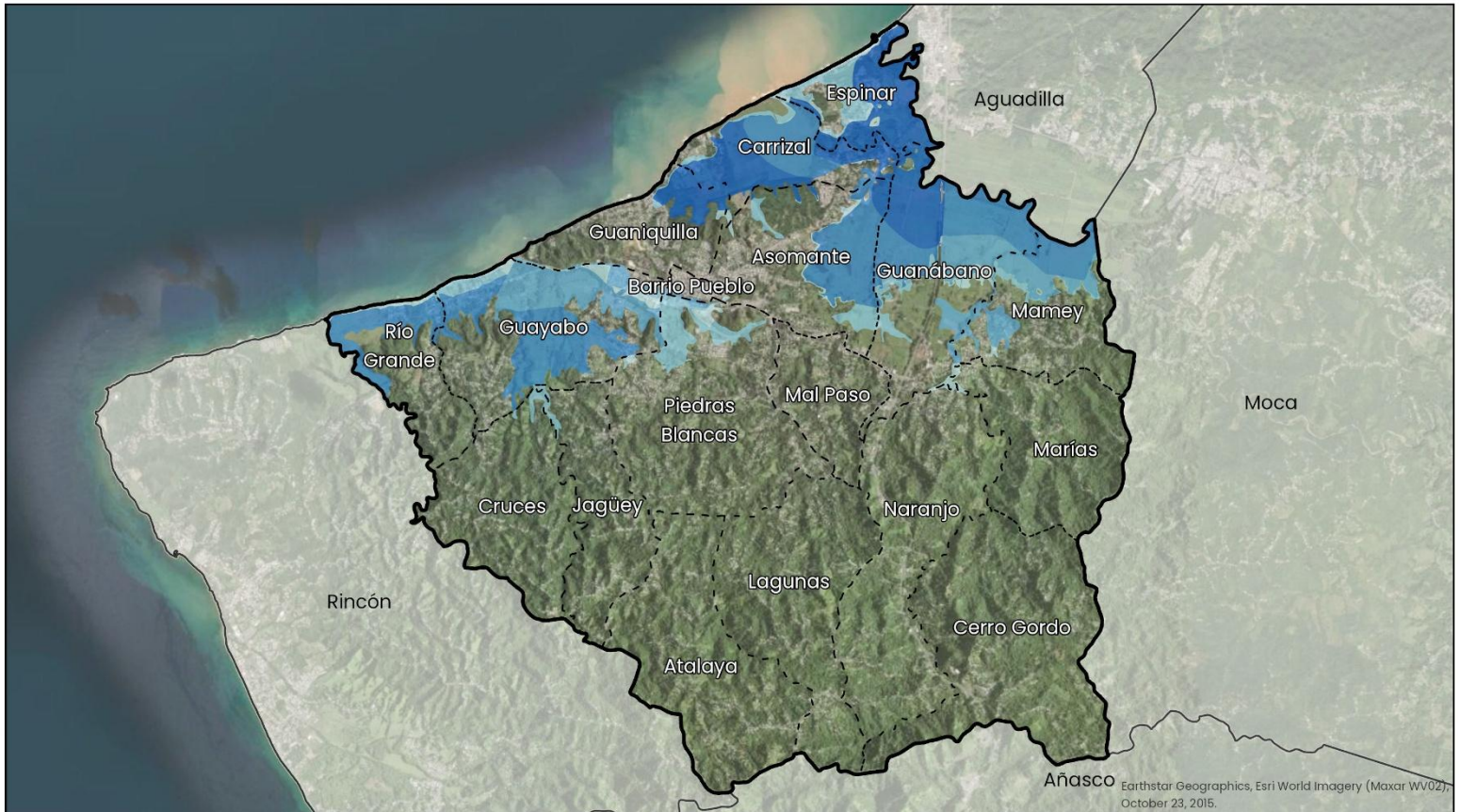
As discussed earlier in this plan, a significant portion of Aguada's population exhibits characteristics associated with social vulnerability. Consequently, flood hazards affecting the municipality's northern coastal and near-coastal sectors may disproportionately impact populations with limited resources and reduced capacity to prepare for, respond to, and recover from flood events.

Research in flood-prone Puerto Rican communities shows that access to economic, material, and social resources strongly influences adaptive capacity, with low-income residents facing significant barriers to elevating homes, purchasing insurance, or relocating away from high-risk zones. These same communities frequently experience “false security” due to structural flood-control measures that reduce perceived risk but do not eliminate underlying exposure, which can worsen long-term vulnerability when residents underestimate future flood potential. Flood impacts also disproportionately affect individuals with limited mobility—including older adults, disabled residents, and those with chronic medical conditions—who may be unable to evacuate rapidly or access emergency shelters during rising waters. The Census Bureau's Community Resilience Estimates indicate that vehicle access, caregiver support, health insurance gaps, and disability prevalence are among the most widespread vulnerability components in the commonwealth, factors that directly

shape whether individuals can flee or recover from flooding (US Census Bureau, 2024), (López Marrero, 2010) .

Map 38.Flooding: Population Exposure

FLOOD: POPULATION EXPOSURE



Source: Puerto Rico Planning Board, Census Tract and Federal Emergency Management Agency (FEMA)

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4.9.2.4 *Natural and Cultural Resources*

In most flood events, water resources are exposed to high levels of contaminants associated with rising water, sewage accumulation, and other hazardous or toxic substances left behind by flooding (Malilay, 2000). This contamination can facilitate the spread of diseases in municipal water bodies and adversely affect local flora and fauna, including humans. For example, prolonged stagnant water after a flood can promote diseases such as dengue and leptospirosis. Following Hurricane María, stagnant water contributed to leptospirosis outbreaks and mosquito proliferation that led to dengue. Leptospirosis is a bacterial disease that affects both humans and animals and can spread through urine from infected animals. These contaminated residues often remain in stagnant water after flooding events.

Floods also lead to the accumulation of debris, including structural remnants, soil, sediments, organic waste, and personal belongings. If not properly managed, this debris can contaminate land and water when burned, abandoned, buried, or dumped into water bodies.

4.9.2.5 *Special Consideration: Repetitive Losses and Severe Repetitive Losses*

In Aguada there are properties insured under the National Flood Insurance Program (NFIP). These properties participate in the NFIP covered by the PRPB. Section 6.5 provides further details on how the municipality can use the NFIP as a mechanism for mitigation planning.

The Municipality has included properties that have experienced repetitive losses and/or severe repetitive losses located in identified flood hazard areas. These properties currently lack descriptions of the type of structures (residential, commercial, institutional, among others). Including this information helps to understand the vulnerability of properties affected by flooding within the jurisdiction and increases the likelihood of qualifying for flood control or prevention grants through programs such as Flood Mitigation Assistance (FMA), Hazard Mitigation Grant Program (HMGP), Housing and Urban Development (HUD), CDBG-DR, and others.

As of December 2025, the National Flood Insurance Program (NFIP) records indicate that the Municipality of Aguada has 75 active flood insurance policies and a total disbursement of \$257,198 associated with Repetitive Loss (RL) and Severe Repetitive

Loss (SRL) properties. Tables 35 through 37 summarize the NFIP coverage, repetitive loss, and severe repetitive loss information available for Aguada.

Table 35. NFIP Policies in force and coverage

Amount of NFIP Policies	Total Disbursement for both RL and SRL Losses
75	\$257,198

Source: Puerto Rico Planning Board

NFIP records identify two Repetitive Loss (RL) properties within the municipality, one of which is currently insured. These properties have generated a total of 11 repetitive loss claims.

Table 36. NFIP Repetitive Losses

Structures with Repetitive Losses (RL)	Insured structures (RL)	Total Repetitive Losses (RL)
2	1	11

Source: Puerto Rico Planning Board

NFIP records also identify one Severe Repetitive Loss (SRL) property within Aguada. Although the property is not currently insured through the NFIP, it has generated a total of nine severe repetitive loss claims.

Table 37. NFIP Severe Repetitive Losses

Structures with Severe Repetitive Losses (SRL)	Insured structures S(RL)	Total Repetitive Losses (SRL)
1	0	9

Source: Puerto Rico Planning Board

The presence of repetitive loss and severe repetitive loss properties indicates that certain areas of Aguada continue to experience recurring flood-related damages. These properties represent locations where mitigation measures may provide significant reductions in future losses and should be considered priorities for flood risk reduction initiatives.

4.9.2.6 Future Conditions (E1-a)

Recent development within flood hazard areas may increase future exposure by placing additional structures and infrastructures in locations subject to flooding. Evaluating the location of recently issued construction permits provides an indication

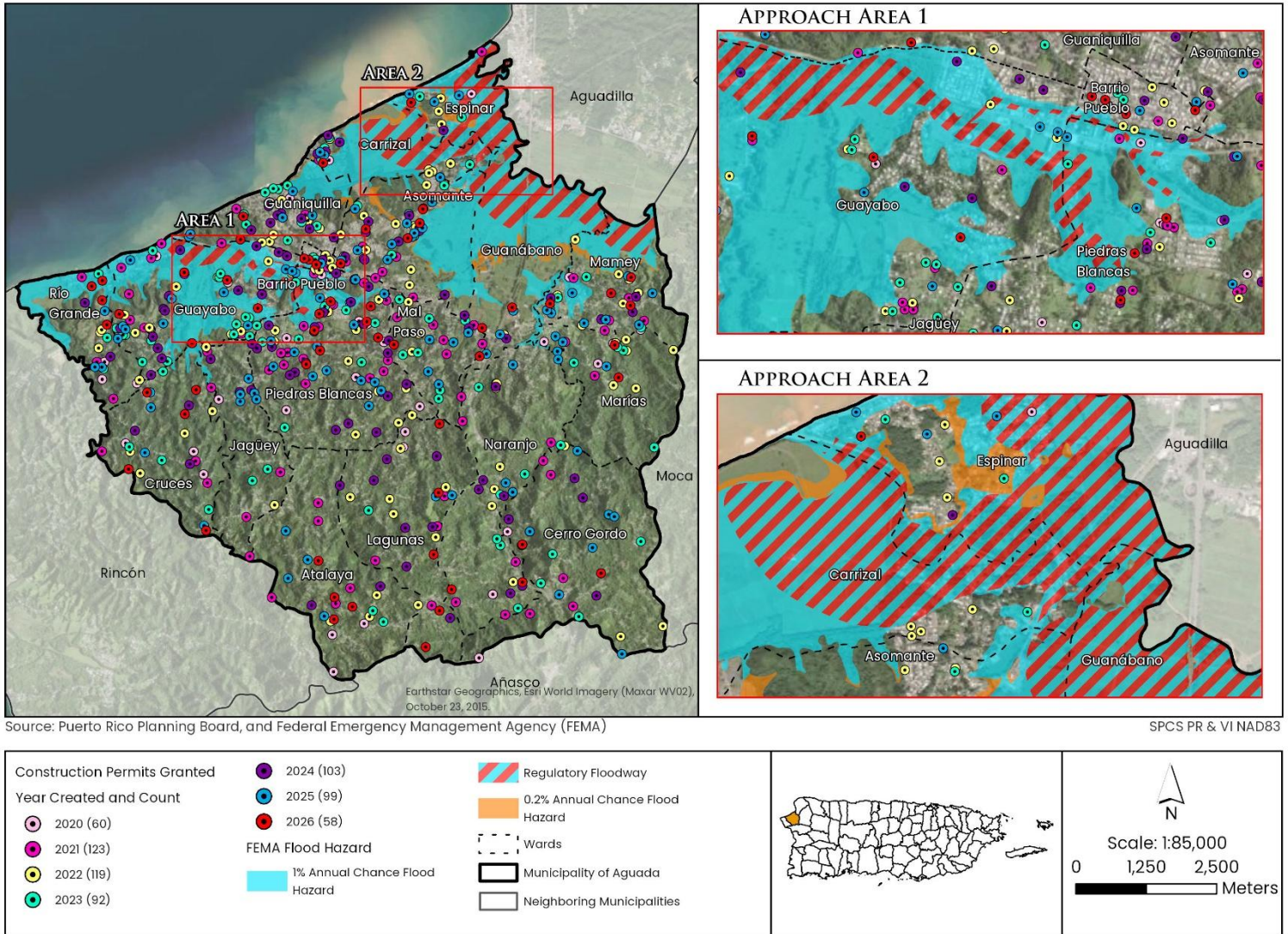
of where growth has occurred relative to FEMA-mapped flood hazard areas.

Map 39 illustrates construction permits issued between 2020 and 2026 in relation to the municipality's mapped flood hazard areas. The map shows that construction activity has occurred throughout Aguada during this period, including within and adjacent to the 1-percent annual chance flood hazard area (100-year floodplain), the 0.2-percent annual chance flood hazard area (500-year floodplain), and the regulatory floodway.

The greatest concentration of recent development within flood-prone areas is observed in the northern portion of the municipality, particularly within the Guaniquilla, Barrio Pueblo, Asomante, Carrizal, Espinar, and Guanábano sectors. Approach Areas 1 and 2 highlight locations where numerous constructions permits overlap or are located immediately adjacent to mapped flood hazard zones.

Although construction permits are distributed throughout the municipality, the map indicates that recent development has also occurred in areas currently identified as subject to flood hazards. The overlap between recent development and mapped flood hazard areas is most evident within the northern portion of Aguada, where both flood-prone areas and development activity are concentrated.

FLOOD: RECENT DEVELOPMENT EXPOSURE



4.10 Tropical Cyclones and other Extreme Wind Events

4.10.1 Description (B1-a)

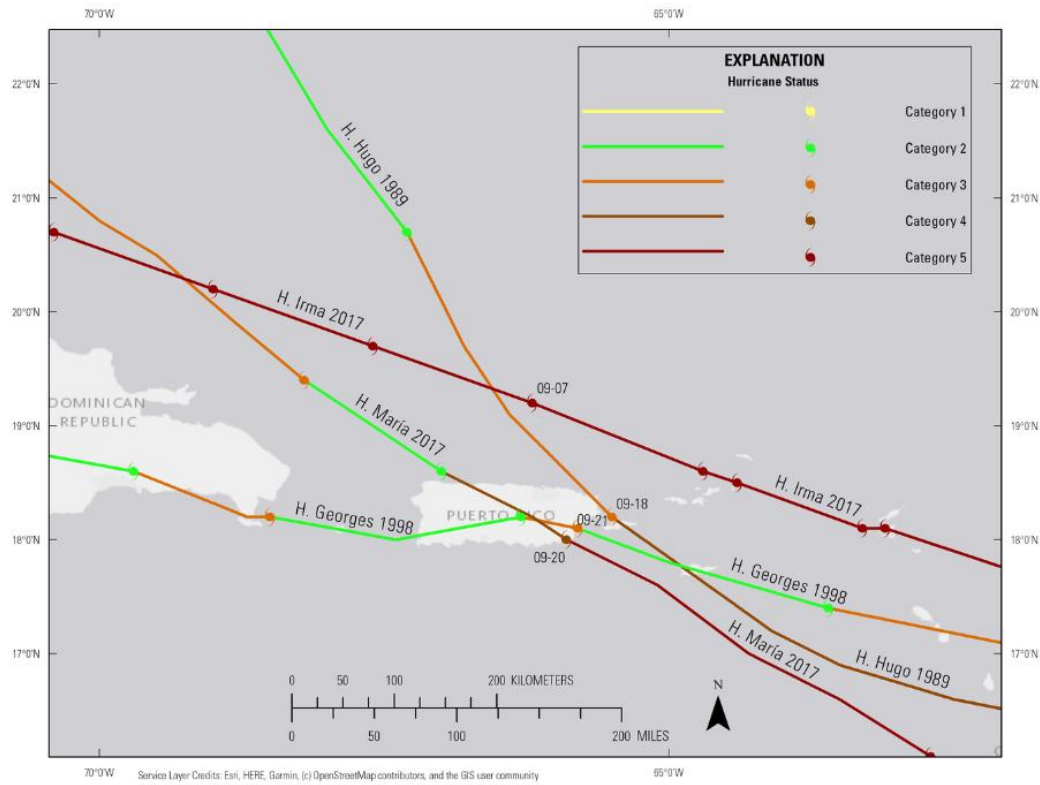
Winds consist of air currents generated in the atmosphere due to variations in pressure. Although these currents are constantly present, when their intensity increases, they can become a high-level hazard. For the purposes of this Plan, we will focus on events severe wind events associated with tropical cyclones and their extreme force (Castro Rivera & López Marrero, *Cartilla de los Ciclonés*, 2018).

This sub-chapter is titled Tropical Cyclones to include phenomena such as tropical storms and tropical depressions. However, hurricanes pose the greatest threat due to their high destructive potential, wide geographic impact, rapid development, and sometimes unpredictable paths. In addition, hurricanes are often accompanied by high tides, storm surges, and heavy rainfall, which may result in landslides and riverine flooding. Since these accompanying hazards are addressed in separate sections, this section will focus specifically on the impact of wind within the municipality.

Figure 21 shows the path of category 2 – 5 hurricanes that have affected Puerto Rico since 1989.¹⁰

¹⁰ Hortense (1996) and Fiona (2022) are not shown since they were category 1 hurricanes when they hit Puerto Rico.

Figure 21. Hurricane Tracks for Hugo (1989), Georges (1998), Irma (2017) and María (2017). Data provided by NOAA with image of ESRI.

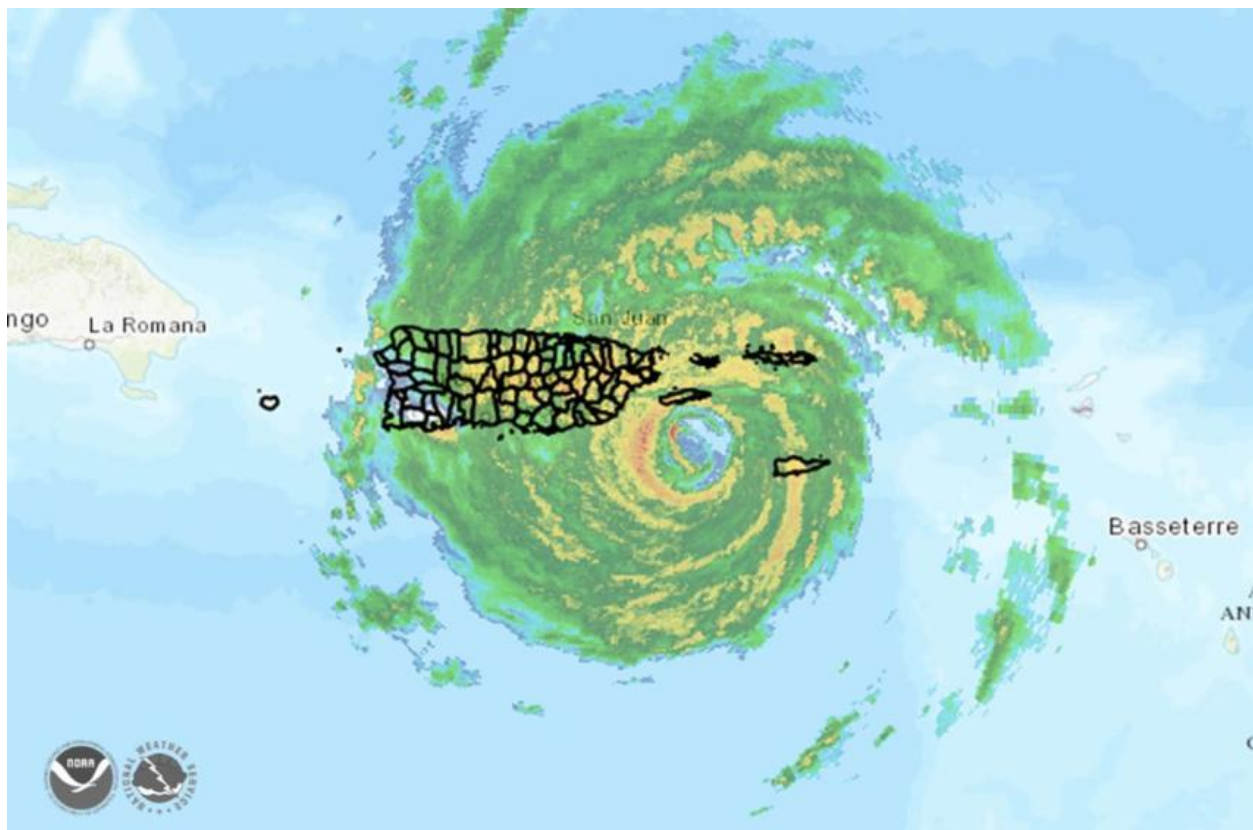


Sources/Usage: Public Domain. [View Media Details](#)

4.10.1.1 Affected Area (B1-b)

Tropical Cyclones are atmospheric systems that can affect the whole island. For example, Figure 22 shows the size of hurricane María (2017) as it approached Puerto Rico.

Figure 22. Hurricane María (2017) as it approaches Puerto Rico



4.10.1.2 Risk Magnitude (B1-c)

Tropical cyclones are the most frequent natural hazard in Puerto Rico, with hurricanes being the most dangerous. Hurricanes are tropical atmospheric systems characterized by sustained wind speeds exceeding seventy-four (74) miles per hour. They develop over warm ocean waters and result from instability caused by the interaction of warm and cool air masses. Tropical cyclones are classified according to sustained wind intensity as follows:

- Tropical Depression: An organized system of clouds with a defined circulation and maximum sustained winds below 39 mph. This represents the formative stage of a tropical cyclone.
- Tropical Storm: An organized system of clouds with a defined circulation and maximum sustained winds ranging from 39 to 73 mph.

- Hurricane: The most intense form of a tropical cyclone, with sustained winds of 74 mph or greater. Hurricanes have a well-defined center with very low barometric pressure. They are categorized from one (I) to five (V), and the strongest can reach wind speeds exceeding 155 mph (Castro Rivera & López Marrero, 2018).

Table 38 shows the Saffir – Simpson Scale of hurricanes and gives historical examples of those passing through or near Puerto Rico.

Table 38. Saffir-Simpson Hurricane Scale

Category	Wind Speed	Description	Historical Example
Tropical Storm	39 – 73 mph	Strong enough to cause tree damage, power outages, and localized flooding, but generally less destructive than a hurricane.	Eloise (1975) Claudette (1979) Frederic (1979) Jeanne (2004) Irene (2011) Isaias (2020) Ernesto (2024)
1	74–95 mph	Winds can cause minor damage to roofs, siding, and trees, with potential for power outages.	Santa Clara ¹¹ (1956) Hortense (1996) Fiona (2022)
2	96–110 mph	Strong winds can cause extensive damage to roofs and trees, leading to widespread power loss.	Marilyn (1995)
3	111–129 mph	Devastating winds can destroy roofs and walls of homes, uproot trees, and cause prolonged outages.	Hugo (1989) Georges (1998)
4	130–156 mph	Catastrophic winds can cause severe structural damage, most trees snapped or uprooted, and power outages lasting weeks.	San Ciriaco (1899) San Ciprian (1932) Donna (1960) David (1979) María (2025)
5	157 mph or higher	Catastrophic winds can result in total roof failure and building collapse, rendering areas uninhabitable for weeks or months.	San Felipe II (1928) Irma (2017)

To assess the vulnerability posed by hurricanes, this LHMP utilizes the 100–year wind

¹¹ Officially known as Hurricane Betsy

event and 500-year wind event as benchmark design standards. A 100-year wind event refers to a wind speed that has a 1% chance of being equaled or exceeded in any given year. Similarly, a 500-year wind event has a 0.2% annual probability of being equaled or exceeded. These terms describe statistical return periods and do not imply that such events occur only once every 100 or 500-years. Rather, they express the likelihood of occurrence in any single year. Wind returns period values are derived through statistical analysis of historical wind speed records using extreme value probability models. These analyses estimate wind intensities associated with specific recurrence intervals and are widely applied in engineering, insurance modeling, and hazard mitigation planning.

These values are critical for structural design standards like the American Society of Civil Engineers Standard 7 (ASCE 7), which specify wind loads for different risk categories, and for insurance companies assessing potential storm damage. For example, typical 3-second gust wind speeds at 33 ft above ground (Exposure Category C) are about 100 mph for a 100-year event and approximately 110–115 mph for a 500-year event. These design speeds ensure safety for buildings, bridges, and critical infrastructure, and help guide emergency planning and financial risk management.

4.10.1.3 Past Events (B1-d)

The following table shows the extreme wind events that received a disaster declaration between 1989 and 2025. One column identifies whether the Municipality of Aguada was designated for Public Assistance (PA), Individual Assistance (IA), or both under each declaration. Table 39 shows a list of presidential disaster declarations since 1987.

Table 39. Tropical Storm Disaster Declaration

Event	Date	Disaster Declaration Number	Aguada Included?	Description
Tropical Storm Ernesto	8/14/2024 – 8/16/2024	DR-4850- PR	Public Assistance: No Individual Assistance: No	The storm's slow movement and moisture-rich environment contributed to prolonged precipitation, particularly in central and eastern municipalities. Parts of Central Puerto Rico recorded 12–14 inches of rainfall in localized areas.
Hurricane Fiona	9/17/2022 – 9/21/2022	DR-4671-PR	Public Assistance: Yes Individual Assistance: Yes	Hurricane Fiona struck Puerto Rico in September 2022, unleashing torrential rains—up to 31.22 inches of rainfall over 72 hours in Ponce, nearly matching the accumulation from Hurricane Maria. This deluge led to catastrophic flooding, with 7 to 20 inches common across most of the island and localized spots exceeding 30 inches.
Tropical Storm Isaías	9/29/2020– 9/30/2020	DR-4560-PR	Public Assistance: No Individual Assistance: No	Although the center of Tropical Storm Isaías did not make landfall on the island, the system left a large amount of rain in its path, causing flooding throughout Puerto Rico. Rainfall accumulation of up to 10 inches was recorded around the island.

Event	Date	Disaster Declaration Number	Aguada Included?	Description
Hurricane María	9/20/2017	DR-4339-PR	Public Assistance: Yes Individual Assistance: Yes	Hurricane Maria (2017) was one of the most destructive tropical cyclones affecting Puerto Rico in recent history. Although impacts varied across the island, Aguada experienced significant effects from hurricane-force winds, prolonged rainfall, power outages, infrastructure damage, and disruptions to essential services. Strong winds caused damage to homes, public facilities, vegetation, and utility systems, while heavy rainfall contributed to hazardous conditions and prolonged recovery efforts. The event exposed the municipality's vulnerability to severe tropical cyclone impacts and highlighted the importance of resilient infrastructure, emergency preparedness, and effective response capabilities.
Hurricane Irma	9/5/2017	DR-4336-PR	Public Assistance: Yes Individual Assistance: No	On September 5, 2017, Hurricane Irma impacted Puerto Rico; an Emergency Declaration was issued for the Island. On September 6, 2017, a Major Disaster Declaration was issued following Hurricane Irma's passage. Two people died due to torrential rains before the hurricane: a man died in Orocovis after falling from his ladder while repairing his roof; another man on the coast in Capitanejo died after being struck by lightning. Wave heights in Puerto Rico reached 9 meters, and sustained winds of 111 mph were recorded in Culebra.

Event	Date	Disaster Declaration Number	Aguada Included?	Description
Tropical Storm María ¹²	9/8/2011 – 9/11/2011	DR-4040-PR	Public Assistance: No Individual Assistance: No	Tropical Storm (later Hurricane) María formed in early September 2011 and passed near Puerto Rico, bringing significant heavy rainfall and tropical storm conditions to the island. The storm caused widespread flooding that inundated numerous roadways and homes; floodwaters near Patillas destroyed several homes and bridges, and approximately 150 houses in Yabucoa were flooded and damaged
Hurricane Irene	8/22/2011	DR-4017-PR	Public Assistance: Yes Individual Assistance: No	Total rainfall reached 22 inches over three days, with the eastern region being the most affected—the same area that had already received over 6 inches earlier in August during the close passage of Tropical Storm Emily. The Grande River in the municipality of Manatí recorded its third-highest level in history, surpassed only during Hurricane Hortense (1996) and Hurricane Georges (1998). The Puerto Nuevo River near Hato Rey reached its fourth-highest level on record. Flooding was severe enough to cause infrastructure stress and dangerous conditions across multiple municipalities. Tragically, there was one direct fatality attributed to Irene, due to drowning.

¹² Tropical Storm María was a tropical system that pass to the northeast of Puerto Rico in 2011 and that caused flooding in the Island. Not to be confused with the 2017 Hurricane María. The name “María” was retired from the official Atlantic hurricane season list of names after 2017.

Event	Date	Disaster Declaration Number	Aguada Included?	Description
Tropical Storm Jeanne	9/14/2004 – 9/19/2004	DR-1152-PR	Public Assistance: Yes Individual Assistance Yes	Tropical Storm Jeanne crossed Puerto Rico on September 15, 2004, as a strong tropical storm with maximum sustained winds around 70 mph (110 km/h), producing gusts up to 72 mph (≈116 km/h). The winds caused widespread power and water outages, with numerous reports of structural damage to homes, uprooted trees, fallen utility poles, and significant impacts on infrastructure across the island. The storm resulted in eight fatalities in Puerto Rico—four direct and four indirect, including deaths during preparations and carbon monoxide poisoning. Damages were estimated at approximately \$169.5 million (2004 USD), making Jeanne the most destructive tropical cyclone to impact Puerto Rico since Hurricane Georges in 1998.

4.10.1.4 Tornadoes

According to NOAA's National Centers for Environmental Information (NCEI), three tornado events have been reported in Aguada since 2002. An F0 tornado occurred on October 4, 2002, resulting in approximately \$5,000 in property damage. Additional tornadoes were reported on October 1, 2013 (EF0), and July 16, 2023 (EF1). No deaths or injuries were reported for any of these events. The 2013 tornado caused approximately \$10,000 in property damage, while no property damage was reported for the 2023 event. Table 40 presents the NCEI database of reported tornadoes in Puerto Rico (NOAA, 2025).

Table 40. NCEI Reported Tornadoes in Puerto Rico

Municipality	Date	Type	Magnitude	Deaths	Injuries	Property Damage	Crop Damage
Guaynabo	5/1/1995	Tornado	F0	0	0	\$0.00	\$0.00
Cabo Rojo	7/20/1999	Tornado	F0	0	0	\$0.00	\$0.00
Cabo Rojo	9/6/1999	Tornado	F0	0	0	\$0.00	\$0.00
Ceiba	9/8/1999	Tornado	F0	0	0	\$0.00	\$0.00
Caguas	2/23/2000	Tornado	F0	0	0	\$0.00	\$0.00
Adjuntas	8/25/2000	Tornado	F0	0	0	\$5,000.00	\$0.00
Añasco	6/3/2001	Tornado	F0	0	0	\$20,000.00	\$0.00
Aguada	10/4/2002	Tornado	F0	0	0	\$5,000.00	\$0.00
Cabo Rojo	10/16/2004	Tornado	F0	0	0	\$0.00	\$0.00
Aguadilla	6/22/2005	Tornado	F0	0	0	\$15,000.00	\$0.00
Mayaguez	6/15/2006	Tornado	F0	0	0	\$30,000.00	\$0.00
Añasco	8/6/2007	Tornado	EF0	0	0	\$35,000.00	\$1,000.00
Aguadilla	8/25/2009	Tornado	EF0	0	0	\$15,000.00	\$0.00
Moca	8/7/2011	Tornado	EF0	0	0	\$80,000.00	\$0.00
Lares	9/13/2012	Tornado	EF0	0	0	\$30,000.00	\$0.00
Aguada	10/1/2013	Tornado	EF0	0	0	\$10,000.00	\$0.00
Manatí	11/18/2016	Tornado	EF0	0	0	\$10,000.00	\$0.00
Trujillo Alto	3/26/2017	Tornado	EF0	0	0	\$0.00	\$0.00
Lajas	7/27/2019	Tornado	EF0	0	0	\$100,000.00	\$0.00
Bayamón	9/30/2019	Tornado	EF0	0	0	\$0.00	\$0.00
Arecibo	5/1/2022	Tornado	EF1	0	0	\$0.00	\$0.00
Las Piedras	3/16/2023	Tornado	EF0	0	0	\$40,000.00	\$0.00
Aguada	7/16/2023	Tornado	EF1	0	0	\$0.00	\$0.00
Aguadilla	8/9/2023	Tornado	EF0	0	0	\$40,000.00	\$0.00
Arecibo	5/2/2024	Tornado	EF0	0	0	\$7,500.00	\$0.00

Municipality	Date	Type	Magnitude	Deaths	Injuries	Property Damage	Crop Damage
Totals:				0	0	\$442,500.00	\$1,000.00

Although tornadoes are relatively uncommon in Puerto Rico, the occurrence of three documented tornado events in Aguada demonstrates that localized tornado hazards can affect the municipality and should be considered in hazard mitigation planning. Table 41 to Table 43 shows the details of the tornado reported in Aguada.

Table 41. Reported Tornadoes in Aguada in 2002

Event	Tornado
-- Scale	F0
-- Length	.5 Miles
-- Width	15 Yards
State	Puerto Rico
County/Area	Mayaguez and vicinity
WFO	SJU
Report Source	General Public
NCEI Data Source	PDS
Begin Date	2002-10-04 14:50 AST
End Date	2002-10-04 15:00 AST
End Location	AGUADA
Deaths Direct/Indirect	0/0 (fatality details below, when available...)
Injuries Direct/Indirect	0/0
Property Damage	5K
Crop Damage	
Episode Narrative	Emergency Managers reported that a resident of Aguada, Malpaso sector, sighted a tornado. A house was affected as the zinc roof was detached from the rest of the house.

Table 42. Reported Tornadoes in Aguada in 2013

Event	Tornado
-- Scale	EF0
-- Length	0.3 Miles
-- Width	10 Yards
State	Puerto Rico
County/Area	Aguada
WFO	SJU

Report Source	Social Media
NCEI Data Source	CSV
Begin Date	2013-10-01 14:43 AST-4
Begin Location	14.9N Aguada
Begin Lat/Lon	18.3349/-67.1876
End Date	2013-10-01 14:46 AST-4
End Location	15.12N Aguada
End Lat/Lon	18.3379/-67.1909
Deaths Direct/Indirect	0/0 (fatality details below, when available...)
Injuries Direct/Indirect	0/0
Property Damage	10.00K
Crop Damage	0.00K
Episode Narrative	Upper-level trough combined with strong daytime heating and sea breeze convergence to produce scattered to numerous showers with strong thunderstorms mainly over the western section of Puerto Rico.
Event Narrative	Based on information from videos and photos obtained, a tornado touched down at Barrio Atalaya in Aguada, producing structural damage to homes and shelters, downed trees, overturned cargo trailers, downed power lines and loss of electricity.

Table 43. Reported Tornadoes in Aguada in 2023

Event	Tornado
-- Scale	EF1
-- Length	1.5 Miles
-- Width	70 Yards
State	Puerto Rico
County/Area	Aguada
WFO	SJU
Report Source	Emergency Manager
NCEI Data Source	CSV
Begin Date	2023-07-16 15:08 AST-4
Begin Location	17.23N Aguada
Begin Lat/Lon	18.3677/-67.2
End Date	2023-07-16 15:19 AST-4
End Location	18.4N Aguada
End Lat/Lon	18.3835/-67.2107
Deaths Direct/Indirect	0/0 (fatality details below, when available...)

Injuries Direct/Indirect	0/0
Property Damage	0.00K
Crop Damage	0.00K
Episode Narrative	A strong thunderstorm developed over northwestern Puerto Rico on July 16th and produced a tornado near Road 411 on the border of Barrio Asomante and Barrio Guayabo around 3:08 PM AST and lasted around 11 minutes. The tornado was moving towards the north-northwest from Barrio Guayabo to Balneario Pico de Piedra, where it transitioned into a waterspout over the coastal waters before dissipating.
Event Narrative	Emergency management reported that a preliminary short-duration tornado damaged power poles and cables and caused them to fall over a one-way street near Epifanio Estrada School in Aguada. This was reported in Road PR-411, Km 2.9. Part of this road and the one-way street were obstructed by the debris. One house suffered major damage, including partial loss of the roof. This resulted in significant interior damage to the house. Another house lost its roof covering material and metal siding. Numerous trees were uprooted and snapped along the tornado track.

4.10.1.5 Future event probabilities (B1-e)

According to the Colorado State University Tropical Cyclones, Radar, Atmospheric Modeling and Software Team, the following average annual probabilities apply for storms coming ashore or passing within 50 miles of Puerto Rico: (Colorado State University, 2026)

- Average probability of a named storm coming ashore or within 50 miles of Puerto Rico: 40%
- Average probability of a hurricane coming ashore or within 50 miles of Puerto Rico: 24%
- Average probability of a major hurricane coming ashore or within 50 miles of Puerto Rico: 9%

4.10.2 Risk Analysis (B2-a, B2-b)

4.10.2.1 Estimated Losses

Table 44 presents the municipality's exposure to Tropical Cyclone and Extreme Winds based on the FEMA National Risk Index. The analysis indicates that approximately 31.3 square miles are exposed to this hazard, affecting an estimated building inventory valued at nearly \$5.0 billion. In addition, approximately 38,125 residents are potentially exposed to Tropical Cyclone and Extreme Winds events. When building value, population, and population equivalency are combined, the municipality's total exposed assets are estimated at approximately \$447.2 billion.

Table 44. Tropical Cyclone and Extreme Winds Exposure

Exposure - Impacted Area (sq mi)	Exposure - Building Value	Exposure - Population	Exposure - Population Equivalence	Exposure - Total
31.257403	\$4,957,844,701	38124.99453	\$442,249,936,557	\$447,207,781,258

Source FEMA NRI

The expected annual loss represents the average annualized economic impact associated with Tropical Cyclone and Extreme Winds events. These losses include damage to buildings as well as economic impacts associated with affected populations.

Table 45. Expected Annual Loss to Tropical Cyclone and Extreme Winds

Expected Annual Loss - Building Value	Expected Annual Loss - Population	Expected Annual Loss - Population Equivalence	Expected Annual Loss - Total
\$21,163,498	0.065477	\$759,540	\$21,923,038

Source FEMA NRI

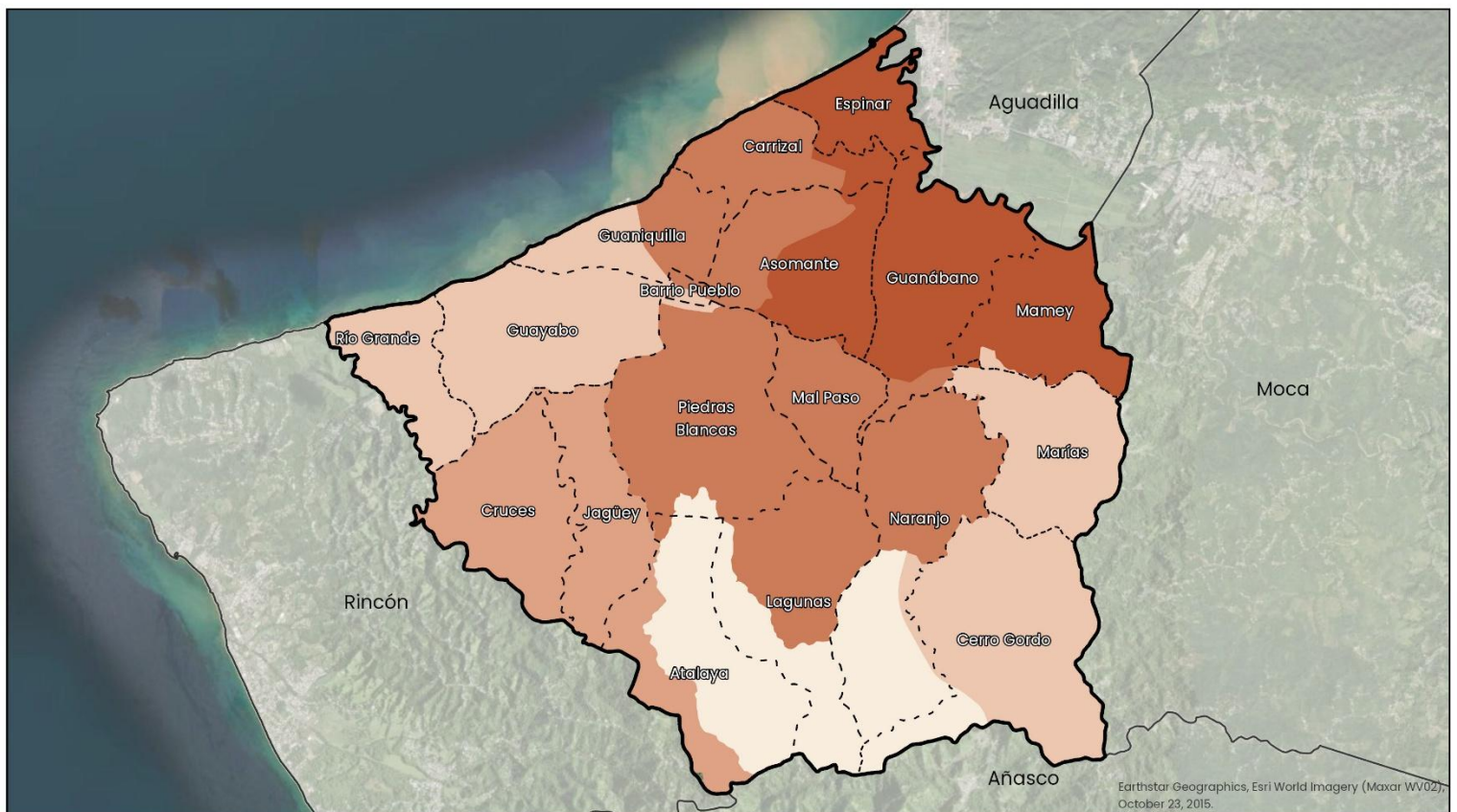
Maps 40 and 41 illustrate the estimated number of damaged buildings associated with the 500-year and 100-year tropical cyclone events, respectively. Both maps show a similar spatial distribution of potential building damage throughout Aguada. The highest concentrations of damaged buildings are projected within the northern portion of the municipality, particularly in the Espinar, Carrizal, Asomante, Guanábano, and Mamey wards. Moderate levels of building damage are projected across portions of Guaniquilla, Barrio Pueblo, Piedras Blancas, Mal Paso, Naranjo, and Lagunas. Lower levels of building damage are projected within portions of Cruces, Jaguey, Atalaya, and Río Grande.

Map 40 shows the estimated number of damaged buildings associated with a 500-year tropical cyclone event by ward, while Map 41 shows the estimated number of

damaged buildings associated with a 100-year tropical cyclone event by ward. The 500-year event is projected to result in greater building damage than the 100-year event. However, both scenarios indicate a similar spatial distribution, with the highest concentrations of damaged buildings occurring in the northern portion of Aguada, particularly within the Espinar, Carrizal, Asomante, Guanábano, and Mamey wards.

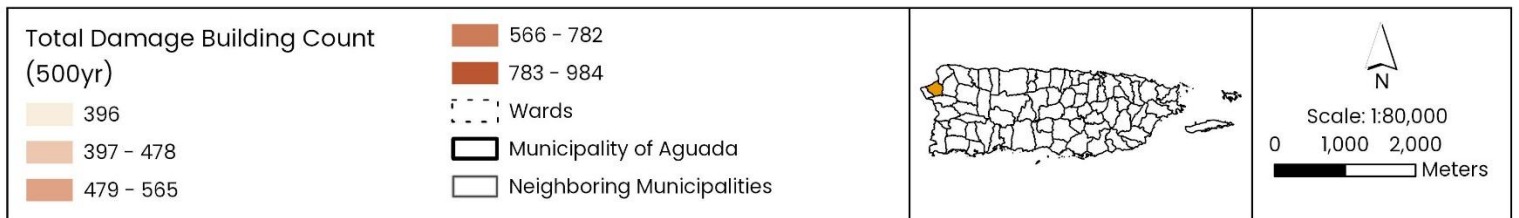
Map 40. Tropical Cyclone: Total Damaged Buildings 500-Year Event

TROPICAL CYCLONE: TOTAL DAMAGED BUILDINGS 500-YEAR EVENT



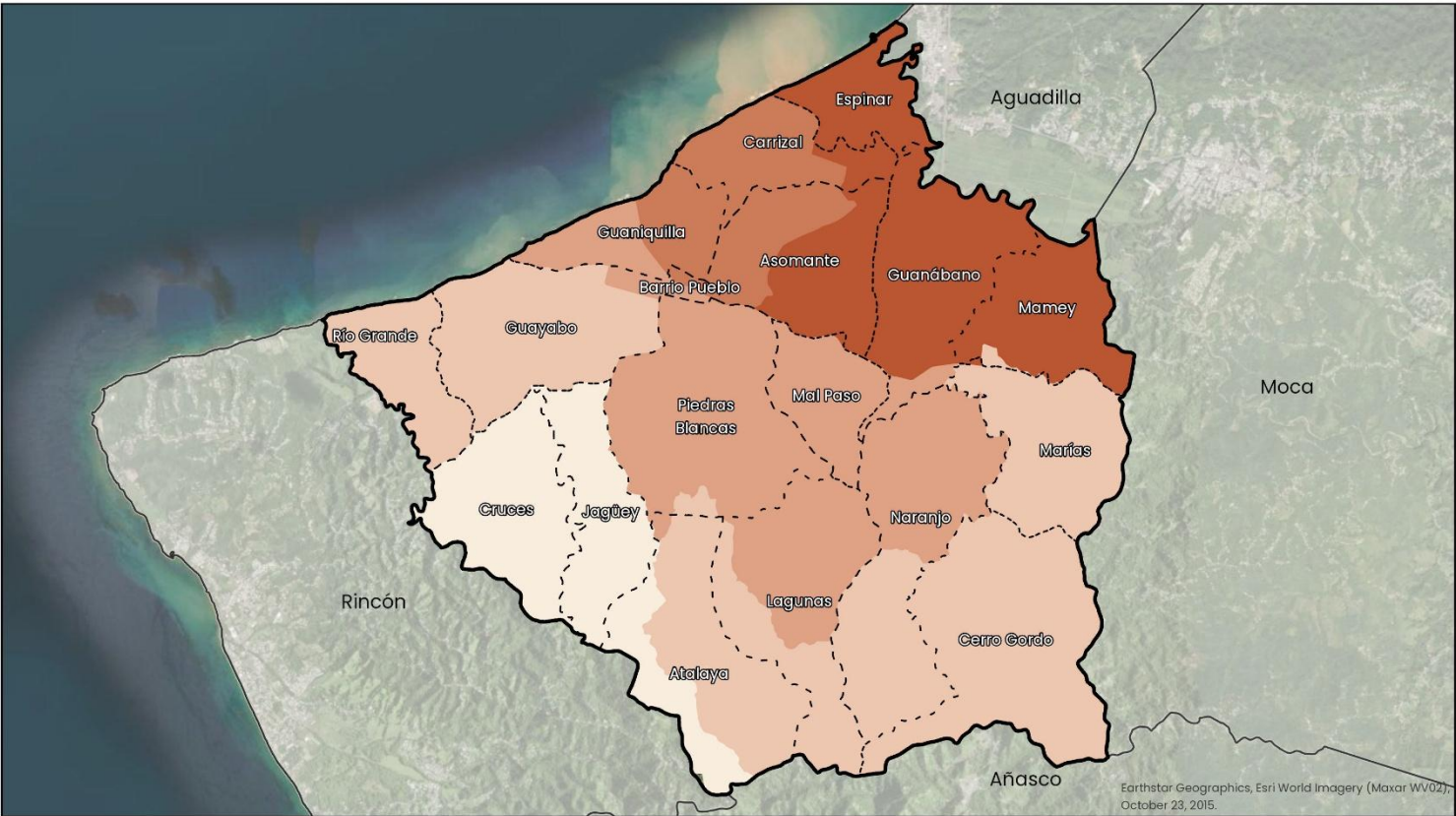
Source: Puerto Rico Planning Board and Hazus 6.1 Output

Earthstar Geographics, Esri World Imagery (Maxar WV02), October 23, 2015. SPCS PR & VI NAD83



Map 41. Tropical Cyclone: Total Damaged Buildings 100-Year Event

TROPICAL CYCLONE: TOTAL DAMAGED BUILDING 100-YEAR EVENT



Source: Puerto Rico Planning Board and Hazus 6.1 Output

Earthstar Geographics, Esri World Imagery (Maxar WV02), October 23, 2015

SPCS PR & VI NAD83

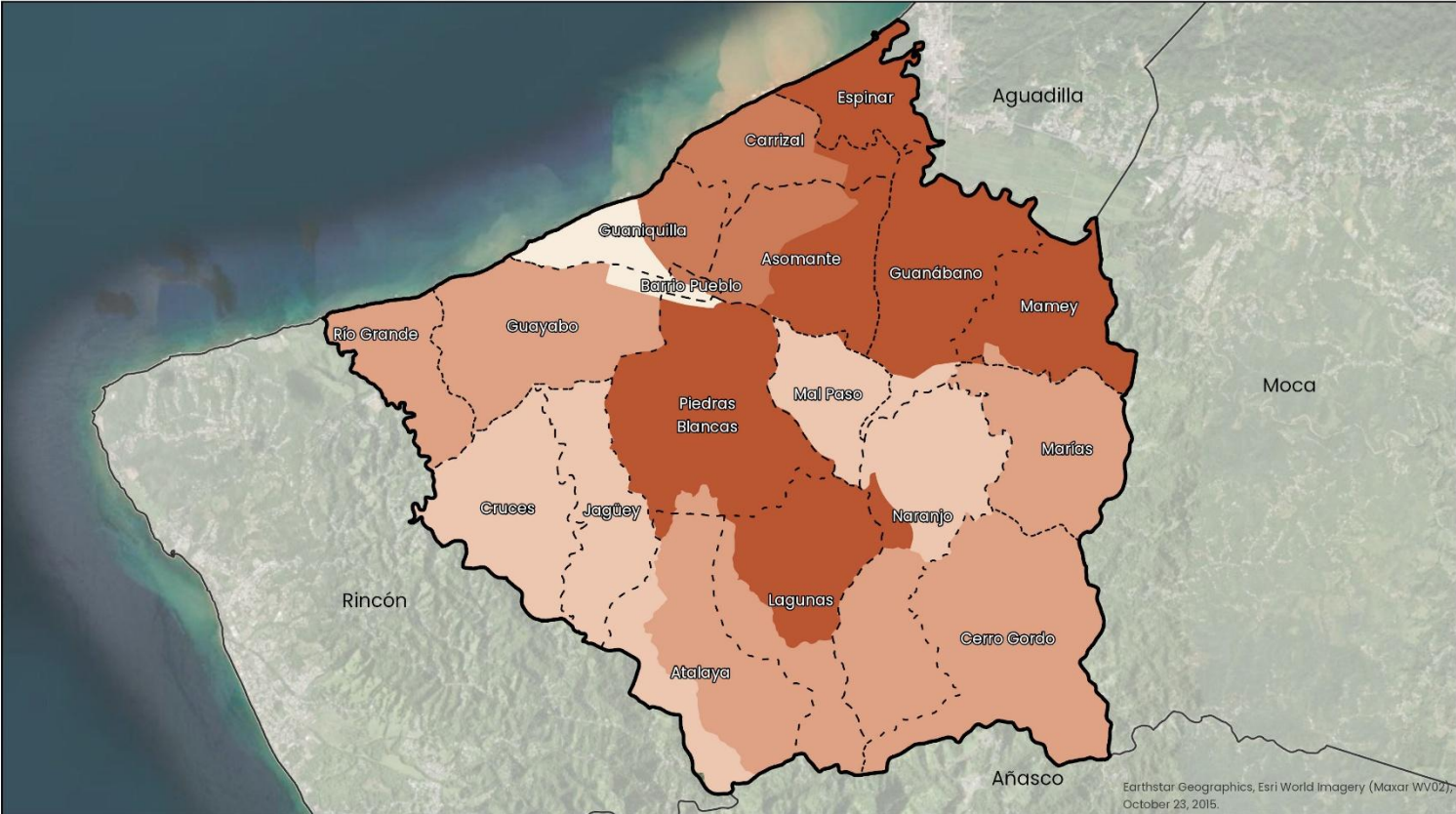


Maps 42 and 43 illustrate the estimated economic losses associated with the 100-year and 500-year tropical cyclone events, respectively. The maps indicate that projected economic losses are distributed throughout the municipality, with the highest losses concentrated in portions of Piedras Blancas and Lagunas. Elevated economic losses are also present within portions of Espinar, Carrizal, Asomante, Guanábano, Mamey, Cruces, and Jaguey.

Lower economic losses are generally observed within Río Grande, Guayabo, Barrio Pueblo, Marías, and Cerro Gordo. Similar spatial patterns are observed in both scenarios; however, the 500-year event produces greater estimated losses than the 100-year event. The distribution of economic losses differs somewhat from the building damage maps, indicating that the areas with the highest projected economic losses do not always correspond to the areas with the highest number of damaged buildings.

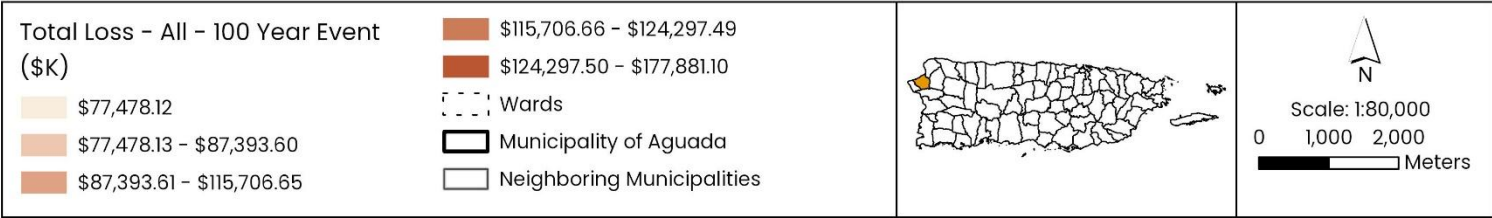
Map 42. Tropical Cyclone: Total Economic Loss 100-year Event (\$K)

TROPICAL CYCLONE: TOTAL ECONOMIC LOSS 100 YEAR EVENT (\$K)



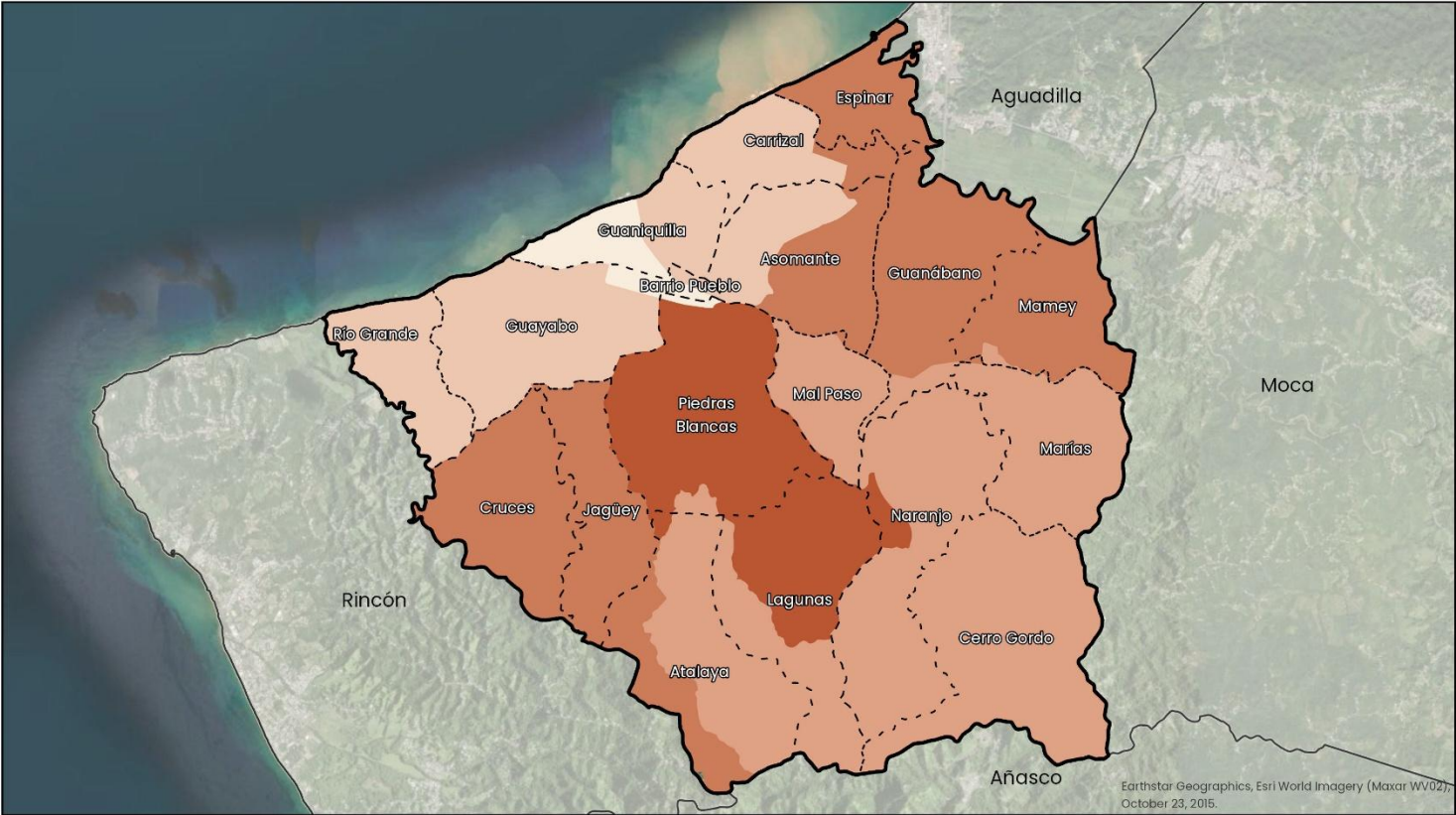
Source: Puerto Rico Planning Board and Hazus 6.1 Output

SPCS PR & VI NAD83



Map 43. Tropical Cyclone: Total Economic Loss 500-year Event (\$K)

TROPICAL CYCLONE: TOTAL ECONOMIC LOSS 500 YEAR EVENT (\$K)



Source: Puerto Rico Planning Board and Hazus 6.1 Output

SPCS PR & VI NAD83



4.10.2.2 *Lifelines and Critical Infrastructure*

Hurricane winds have profound effects on all eight FEMA Community Lifelines, disrupting essential services and infrastructure.

- **Safety and Security** systems are compromised when high winds damage police stations, fire departments, and emergency operations centers, while debris and fallen power lines obstruct emergency routes, delaying rescue efforts.
- **Food, Hydration, and Shelter** lifelines suffer as winds destroy agricultural fields, damage food storage facilities, and tear roofs off homes and shelters, leaving communities vulnerable and displacing thousands.
- In the **Health and Medicine** sector, hospitals and clinics experience roof failures and structural damage, forcing evacuations and interrupting critical care, while pharmacies and supply chains face severe disruptions.
- **Energy** lifeline is particularly vulnerable, as hurricane winds topple transmission towers, snap utility poles, and damage substations, causing widespread power outages that cascade into other lifelines.
- **Communications** systems fail when telecommunication towers and antennas are blown down, severing cellular and internet connectivity and hindering emergency coordination.
- **Transportation** networks are crippled by blocked roads, damaged bridges, and wind-related destruction at airports and seaports, delaying relief efforts and supply deliveries.
- Facilities handling **Hazardous Materials** face increased risks when wind-driven debris ruptures tanks or pipelines, creating environmental hazards and complicating cleanup operations.
- Finally, **Water Systems** are disrupted as treatment plants and pumping stations sustain roof and equipment damage, while elevated storage tanks and distribution infrastructure collapse, interrupting access to clean water for drinking and sanitation. These cascading failures underscore the critical need for wind-resistant design standards and proactive planning to protect lifelines and maintain community resilience during hurricane events.

For planning purposes this LHMP shall assume that all critical infrastructure is equally exposed to this hazard.

4.10.2.3 Social Vulnerabilities

As discussed before in Section 4.10.1.1 a tropical cyclone can impact the whole island. For this LHMP we are going to assume that all the population of Aguada is vulnerable to this hazard. For further details on the Municipality's social vulnerability see section 3.4.4.

4.10.2.4 Natural and Cultural Resources

Hurricane winds caused extensive damage to both natural and cultural resources by exerting extreme mechanical forces on landscapes and built environments. In natural settings, strong winds uproot trees, strip foliage, and break branches, leading to deforestation and habitat loss. This disruption affects biodiversity and can alter ecosystem functions for years. Coastal vegetation such as mangroves is particularly vulnerable, as wind-driven forces weaken root systems and reduce their ability to protect shorelines. Agricultural areas also suffer severe losses, with crops flattened or destroyed, impacting food supply and local economies.

Cultural resources, including historic buildings, monuments, and archaeological sites, are equally at risk from hurricane winds. High wind speeds can dislodge roofing materials, collapse walls, and damage structural integrity, especially in older or unreinforced constructions. Museums, archives, and heritage sites may experience irreparable harm if protective measures are inadequate. The loss of these cultural assets not only affects community identity but also has economic implications for tourism and preservation efforts. Understanding wind speed thresholds and incorporating them into design standards and conservation planning is essential to mitigate these risks and safeguard both natural and cultural heritage.

4.10.2.5 Future Conditions (E1-a)

The risk associated with tropical cyclones is a municipality-wide hazard. Existing and future development throughout Aguada may be affected by hurricane-force winds, heavy rainfall, flooding, and other impacts associated with tropical cyclones. The risk of hurricane is a municipal – wide risk. Every part of the recent development approved by the municipality is equally in risk of being affected by a tropical cyclone.

4.11 Storm Surge

4.11.1 Description

A storm surge is the inland movement of seawater that occurs when a hurricane makes a direct impact on the coast. These storm surges occur due to an atypical increase in the water levels of water bodies. Primarily, storm surges are produced by an excessive rise in water along coastlines because of a massive low-pressure system, rainfall, and strong winds, characteristic of a hurricane or tropical storm (Castro Rivera & López Marrero, 2018).

These factors, inherent to a storm surge, create dangerous conditions at sea and cause extensive devastation after passing through coastal areas. Consequently, this type of natural hazard results in loss of life and severe damage to infrastructure and structures located in the affected areas. They are particularly dangerous when they occur during high tide, combined with the effects of swells and wave action. These factors make it difficult to predict this type of event because they depend on the diversity of tropical systems, the geological formations of the impacted area, and meteorological forecasts (FEMA, 1997).

The maximum potential storm surge for a particular location depends on a series of different factors. Storm surge is a very complex phenomenon because it is sensitive to even slight changes in storm intensity, forward speed, size (radius of maximum winds—RMW), angle of approach to the coast, central pressure (which contributes minimally compared to wind), and the shape of coastal features such as bays and estuaries.

Coastal areas are usually prone to storm surge impacts when an imminent hurricane threat is present. The behavior, magnitude, and impact of storm surge over land vary depending on the hurricane's trajectory. Likewise, the topography and coastal bathymetry of the municipality play an important role in relation to the impact of the surge on affected areas (FEMA, 1997).

4.11.1.1 *Affected Area*

The extent of storm surge impacts within Aguada varies according to storm intensity and local coastal conditions. The following maps identify the areas potentially affected by storm surge under Category 1 and Category 5 hurricane scenarios and illustrate the geographic distribution of this hazard within the municipality.

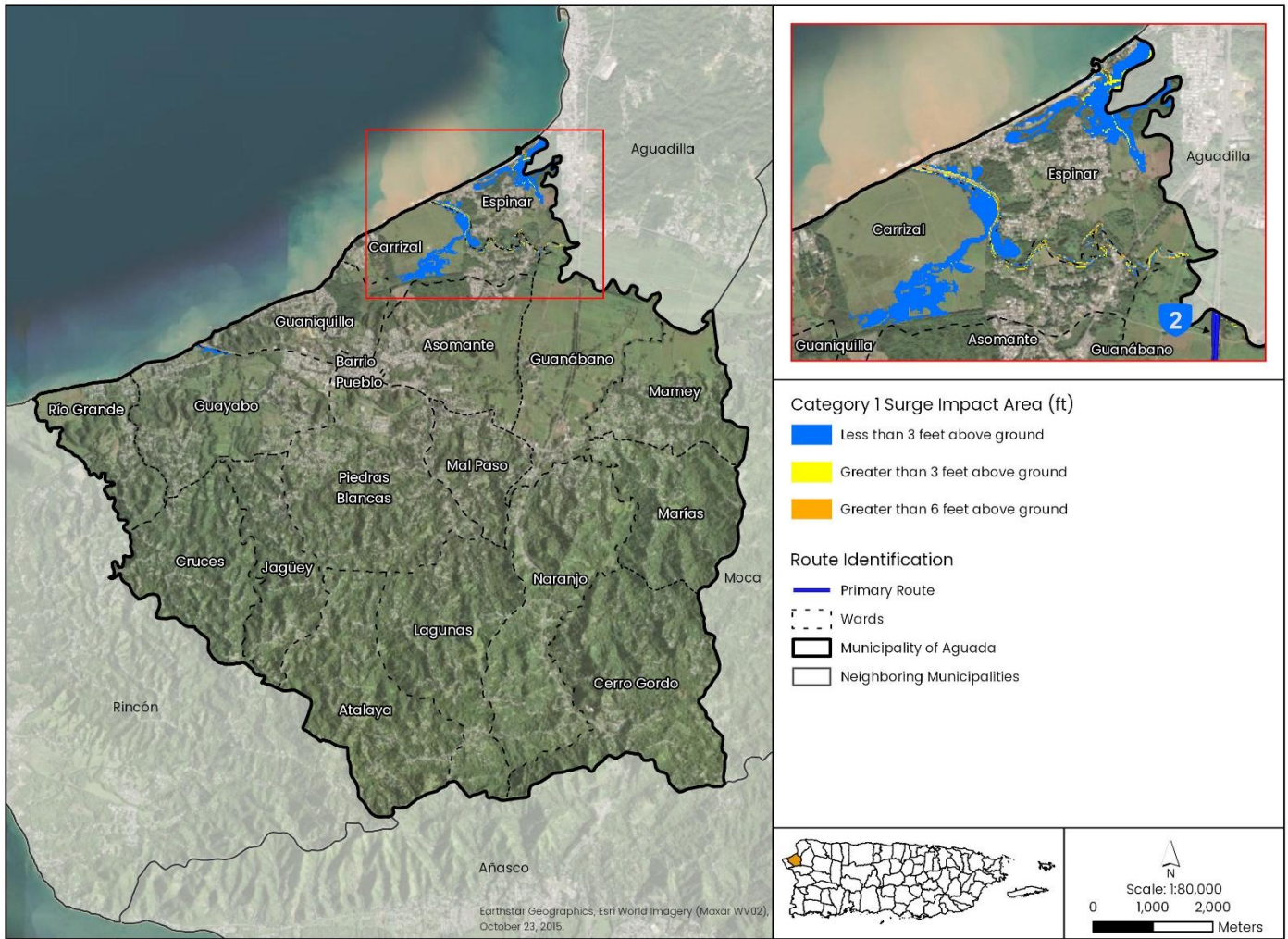
Maps 44 and 45 illustrate the Category 1 and Category 5 storm surge impact areas within the Municipality of Aguada, respectively. In both scenarios, the storm surge hazard is concentrated along the municipality's northern coastal zone. The areas potentially affected by storm surge are primarily located within the Carrizal and Espinar wards, with smaller affected areas extending into portions of Guaniquilla and Guanábano.

The Category 5 storm surge scenario covers a larger area than the Category 1 scenario; however, both maps indicate that storm surge impacts are generally confined to the municipality's coastal zone. Most of the municipality remains outside the mapped storm surge impact areas, with the greatest extent of potential inundation occurring in the northeastern coastal portion of Aguada.

The maps also show that the highest storm surge impact areas are concentrated in low-lying coastal sectors adjacent to the shoreline. As storm surge intensity increases from the Category 1 to the Category 5 scenario, the affected area expands inland within portions of Carrizal and Espinar, while remaining largely limited to the northern coastal portion of the municipality.

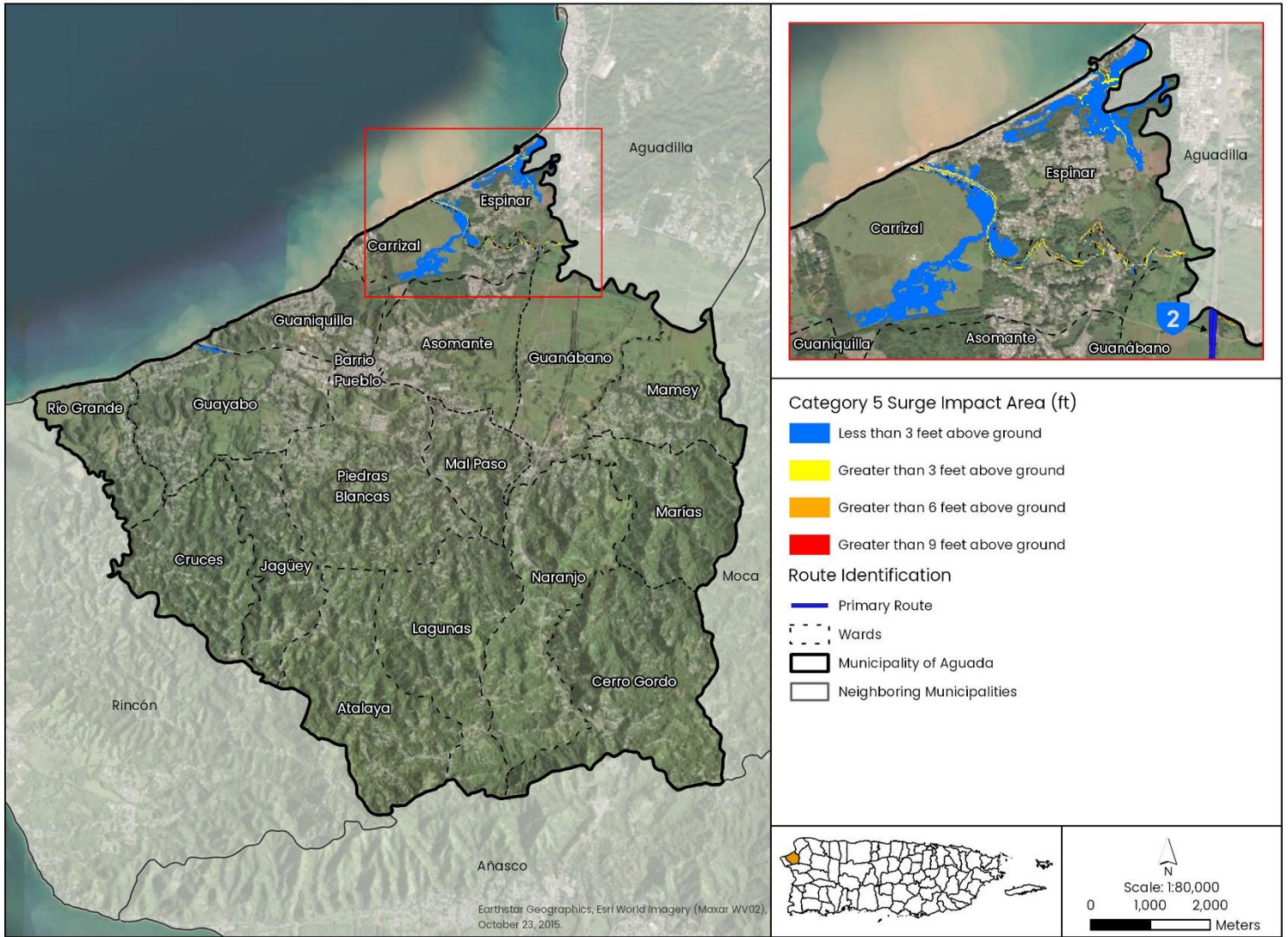
Map 44.Storm Surge: Category 1 Storm Surge Area

STORM SURGE: CATEGORY 1 SURGE IMPACT AREA



Map 45.Storm Surge: Category 5 Storm Surge Impact Area

STORM SURGE: CATEGORY 5 SURGE IMPACT AREA



Source: Puerto Rico Planning Board and National Hurricane Center

SPCS PR & VI NAD83

4.11.1.2 Risk Magnitude

Each of the storm surge maps shows the depth of flooding that would be expected at a given location based on the category of the storm. Flood depth represents the severity/magnitude of the storm surge risk; therefore, when describing this severity/magnitude, it could be expressed in a manner such as, “the greatest flood depth that a community could experience as a result of storm surge with a specific height measure.” The building table can be used to determine a rough estimate of the maximum potential flood depth.

The maps included in the storm surge section of the risk assessment, with reference to the geographic areas affected by this natural hazard, show the impact of this event based on flood depth and according to the occurrence of Category 1 and Category 5 hurricane events. In summary, flood depth represents the severity or magnitude of the storm surge risk, and likewise, there is a correlation between the magnitude of the storm event and the depth of flooding and the extent of land area that will be affected. That is, in most instances, as a storm escalates to higher-magnitude categories, a greater number of neighborhoods and sectors may be impacted by flooding events of greater depth.

Similar to other coastal hazards, storm surges have the potential to expose the population and infrastructure supporting lifelines. Likewise, areas within the municipality that are already prone to flooding may be more severely affected by flooding resulting from storm surge events.

4.11.1.3 Past Events

Hurricane Maria (2017) generated measurable storm surge and storm tide impacts along Puerto Rico’s southeastern and eastern coasts. Post-storm field investigations conducted by the U.S. Geological Survey (USGS) documented storm-tide inundation heights generally ranging from approximately 6 to 9 feet above ground level in coastal municipalities including Humacao, Naguabo, and Ceiba (Byrne, 2019). Lower storm surge levels, typically between 1 and 4 feet, were observed along portions of the northern and western coasts. Although the most catastrophic impacts of Hurricane Maria were driven by extreme rainfall and inland flooding, storm surge contributed to coastal flooding, shoreline erosion, and damage to marinas and port facilities, particularly along exposed eastern shorelines (Byrne, 2019) (Pasch, Penny, & Berg, Hurricane Maria, 2023).

Hurricane Georges (1998) generated storm surge impacts along the southern and eastern coasts, exacerbating coastal inundation and contributing to damage in low-lying coastal communities (Guiney, 1999). More recently, Hurricane Fiona (2022) caused storm surge and wave-driven coastal flooding along Puerto Rico's southern coast, particularly in municipalities facing the Caribbean Sea, despite making landfall as a hurricane of relatively lower wind intensity (Pasch, Reinhart, & Alaka, Hurricane Fiona, 2023).

4.11.1.4 Future Events Probability

The NOAA defines the term storm surge as the rise in ocean level resulting from the effects of wind and the drop in atmospheric pressure associated with hurricanes and other storms. In other words, storm surge is caused primarily by the strong winds of a hurricane or tropical storm; therefore, the probability of occurrence of a storm surge event in the municipality is directly associated with—and increases following—events of strong winds such as hurricanes and will increase or may intensify as such events occur.

To this end, the Sea, Lake, and Overland Surges from Hurricanes model (known as SLOSH, by its English acronym) is a computerized model used by NOAA for the assessment of coastal flooding risk and the operational prediction of storm surge.

According to FEMA, coastal flood risk areas are determined through a statistical analysis of records of riverine flow or currents, storm tides, and rainfall; information obtained through consultations with the community; and a hydrologic and hydraulic analysis. Coastal flood risk areas are delineated or defined in the Flood Insurance Rate Maps (FIRM). These maps also communicate two regulatory flood mapping elements: the extent of land at risk of base flooding (1% annual probability) and the related flood levels in these areas, known as Base Flood Elevations (BFE).

4.11.2 Risk Analysis

4.11.2.1 Estimated Losses

For the FEMA National Risk Index (NRI), storm surge losses are generally represented under the Coastal Flooding hazard category. FEMA does not report a separate "storm surge" Expected Annual Loss (EAL) value for Aguada (FEMA, 2026). To prevent duplication of the data presented in the flood risk analysis, this LHMP will not consider it, as it cannot separate damages created by storm surge or other types of coastal

floods.

4.11.2.2 Lifelines and Critical Infrastructure

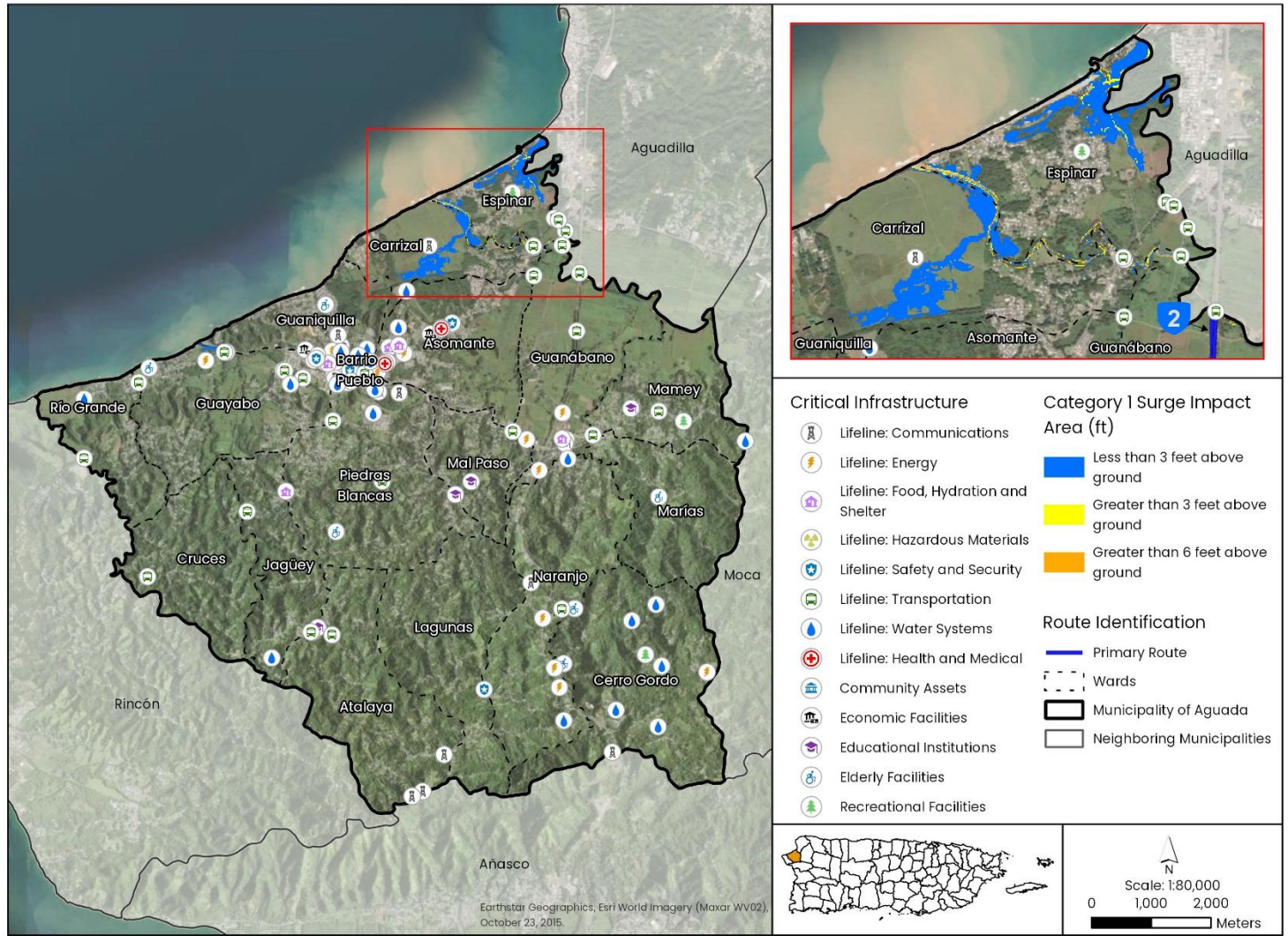
Storm surges pose a significant threat to FEMA-defined community lifelines by inundating critical infrastructure located in coastal and low-lying areas. Transportation lifelines are frequently disrupted when roads, bridges, ports, and evacuation routes are flooded or damaged, restricting evacuation, emergency response, and supply chain movement. Energy lifelines, including power plants, substations, and fuel distribution systems, are highly vulnerable to saltwater intrusion and flooding, which can result in equipment failure and prolonged power outages. Communications lifelines may also be compromised when cell towers, fiber-optic networks, 911 systems, and backup power supplies are damaged or inaccessible due to storm surge flooding. These cascading failures reduce situational awareness and hinder coordination among emergency responders and government agencies. Collectively, impacts on these lifelines significantly reduce a community's ability to protect lives and property during storm surge events. (NOAA, n.d)

Storm surges also have severe consequences for FEMA's health and medical lifeline by flooding hospitals, clinics, long-term care facilities, and pharmaceutical supply chains, sometimes requiring evacuations or service closures. Damage to water and wastewater infrastructure threatens the food, water, and shelter lifeline by limiting access to safe drinking water and sanitation services. Flooded treatment plants and damaged pipelines can lead to water contamination, boil-water advisories, and increased public health risks. Safety and security lifelines are further strained when police, fire, and emergency medical service facilities are damaged or when flooded roadways limit response times. Prolonged disruption of these lifelines slows community recovery and exacerbates social, economic, and health vulnerabilities. These impacts underscore FEMA's emphasis on hazard mitigation, lifeline stabilization, and resilience planning to reduce storm surge.

Map 46 shows the critical infrastructure that would be affected by a storm surge caused by a category 1 hurricane, while Map 47 shows the same but for a category 5 hurricane.

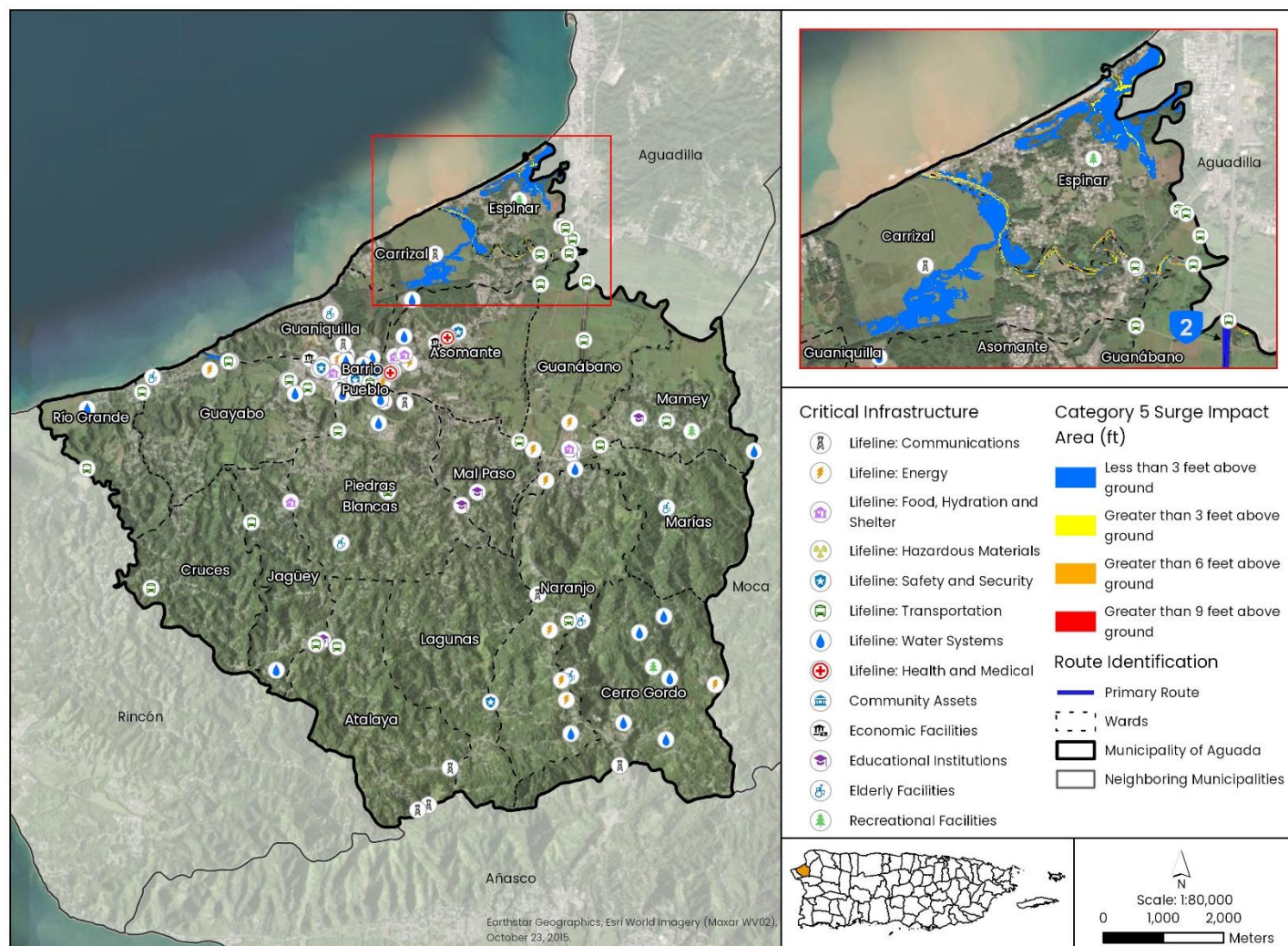
Map 46.Storm Surge: Critical Infrastructure affected by a Cat 1 Storm Surge

STORM SURGE: CRITICAL INFRASTRUCTURE EXPOSURE TO CATEGORY 1 HURRICANE SURGE



Map 47. Storm Surge: Affected Critical Infrastructure Cat 5 Hurricane

STORM SURGE: CRITICAL INFRASTRUCTURE EXPOSURE TO CATEGORY 5 HURRICANE SURGE



4.11.2.3 Social Vulnerabilities

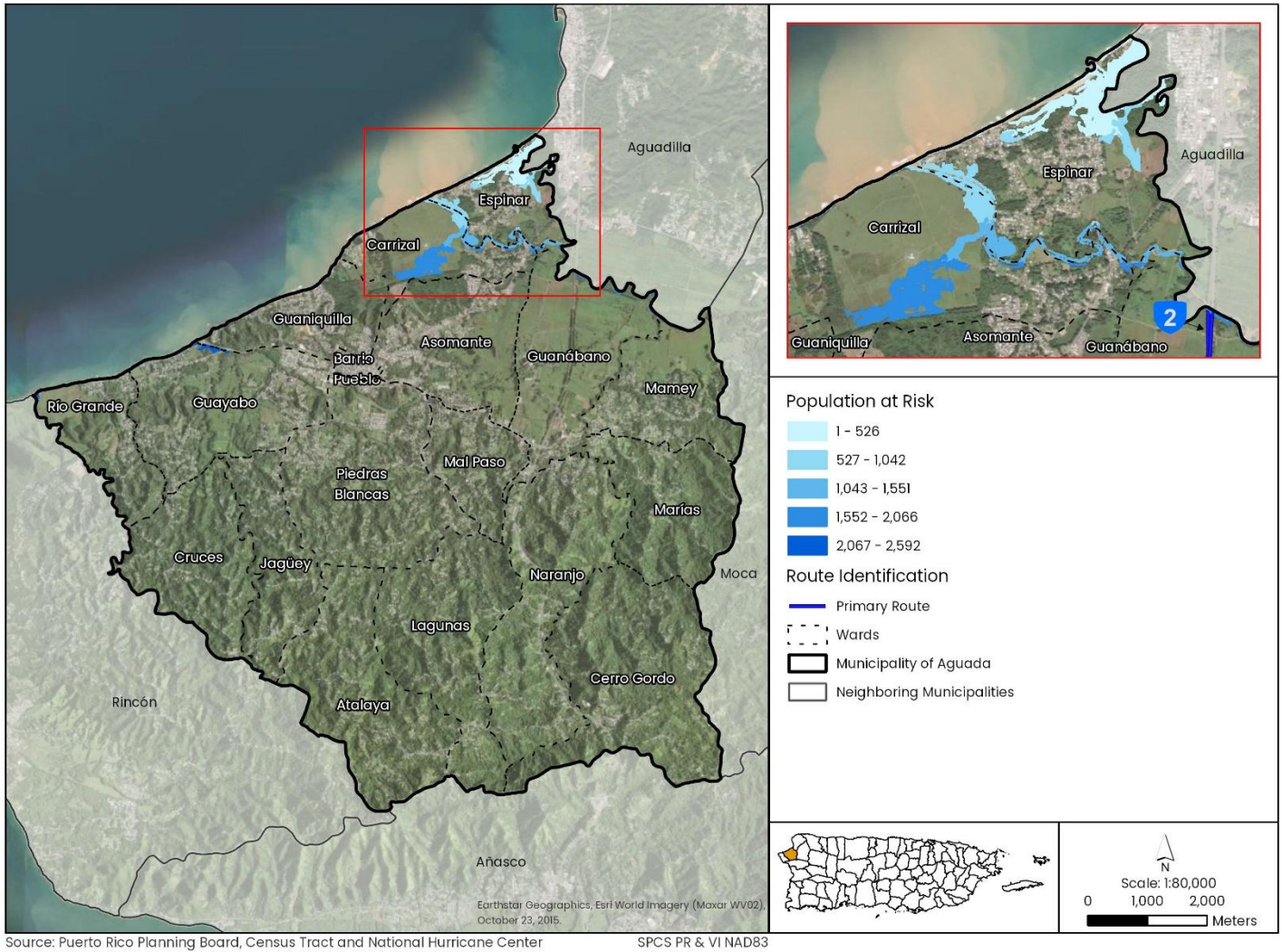
Storm surge events represent a significant social hazard for Puerto Rico due to the Island's extensive coastline, high population density in coastal municipalities, and legacy socioeconomic vulnerabilities. Storm surge-related flooding frequently results in displacement, housing damage, and prolonged interruption of essential services, particularly in low-lying coastal communities and estuarine areas. Studies of hurricanes impacting Puerto Rico, including Hurricane Maria, have shown that flood exposure and displacement are disproportionately concentrated among low-income

households, older adults, and communities with limited access to transportation, healthcare, and economic resources, which delays recovery and increases long-term vulnerability. FEMA and NOAA analyses further indicate that socially vulnerable populations are more likely to reside in surge-prone areas and experience compounded impacts when storm surge coincides with power outages, roadway flooding, and disruptions to water and medical services. (Chowdhury, et al., 2025)

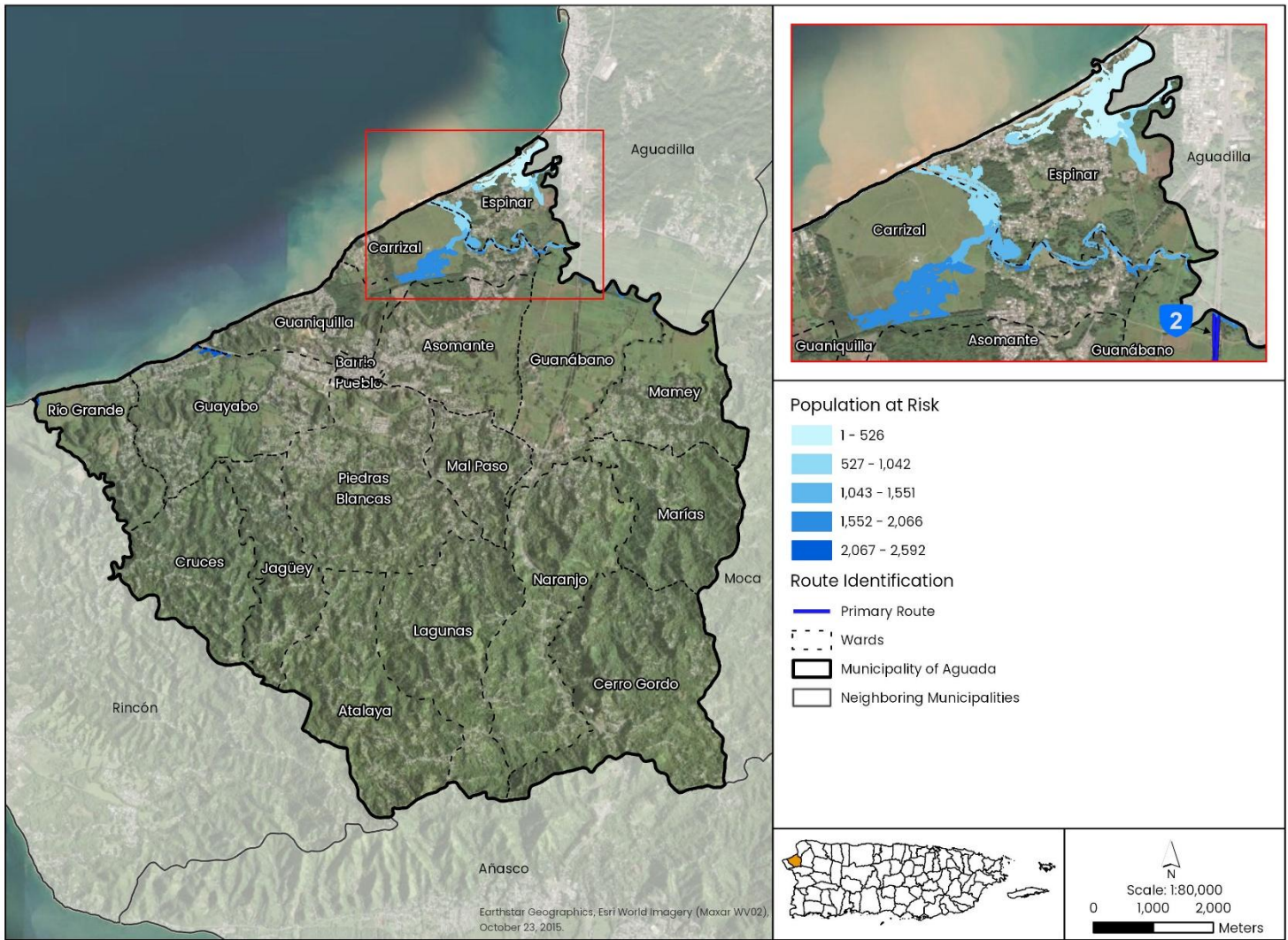
Storm surge flooding also poses serious public health, economic, and equity challenges for Puerto Rico. Flooding of homes, healthcare facilities, and water and wastewater systems increases risks of injury, water contamination, and adverse mental health outcomes, particularly in communities that experience extended power outages and limited access to medical care. Economic impacts are often prolonged, as small businesses, informal workers, and coastal livelihoods face income losses and slower recovery due to limited insurance coverage and financial capacity. Research and federal reviews of disaster recovery programs highlight that inequities in disaster assistance and rebuilding resources can exacerbate social and wealth disparities on the Island, reinforcing the need for mitigation actions that integrate social vulnerability, equitable recovery, and community resilience into storm surge planning. (Chowdhury, et al., 2025)

Storm surge impacts in Aguada could disproportionately affect vulnerable populations, which make up a substantial portion of the municipality. As illustrated in Maps 48 and 49, population exposure increases in low-lying coastal areas vulnerable to storm surge flooding, particularly under the Category 5 scenario. Residents located within these exposed areas may face increased risks of displacement, service disruptions, and adverse public health impacts during storm surge events. Damage to transportation networks, utilities, and community services could further restrict access to essential resources, prolong recovery efforts, and exacerbate existing social and economic challenges within the municipality.

STORM SURGE: POPULATION EXPOSURE TO CATEGORY 1 SURGE



STORM SURGE: POPULATION EXPOSURE TO CATEGORY 5 SURGE



4.11.2.4 Natural and Cultural Resources

Storm surge poses a significant natural hazard to Puerto Rico's coastal and near-coastal environments due to the Island's extensive shoreline, low-lying coastal plains, and concentration of sensitive ecosystems. Surge-driven flooding and wave action can cause severe erosion, saltwater intrusion, and habitat degradation in mangroves, coastal wetlands, estuaries, seagrass beds, and coral reef systems that are critical to biodiversity, fisheries, and natural coastal protection. These ecosystems can experience vegetation die-off, sediment redistribution, and long-term loss of ecological functions such as flood attenuation and water filtration following storm surge events. Repeated storm surge exposure can permanently alter coastal geomorphology and reduce the buffering capacity of natural systems, increasing vulnerability of inland areas and amplifying future flood risk across Puerto Rico's coastal municipalities (Ganz, Duan, & Ji, 2023).

Storm surge also presents substantial risks to Puerto Rico's cultural and historic resources, many of which are concentrated in coastal zones and historic town centers. Flooding and erosion associated with storm surge events can damage or destroy historic buildings, archaeological sites, cemeteries, and cultural landscapes, including Spanish-era structures and Indigenous archaeological resources located near the coast. In addition to physical damage, storm surge-related displacement can disrupt traditional cultural practices and undermine community identity tied to historic places and coastal livelihoods. FEMA and its federal partners recognize the vulnerability of cultural resources to coastal flooding and support mitigation, documentation, and recovery efforts through programs such as the Heritage Emergency National Task Force, emphasizing the importance of incorporating cultural resource protection into hazard mitigation planning for Puerto Rico.

Storm surge impacts in Aguada could cause significant damage to both environmental and cultural resources through coastal flooding, erosion, and saltwater intrusion. Flooding and wave action could erode beaches and affect coastal habitats that provide ecological value and natural protection against flooding. These impacts can degrade wildlife habitat, reduce water quality, and affect marine and coastal resources that support recreation and local economic activity. From a cultural perspective, storm surge could damage coastal communities, recreational facilities, and sites of local historical or cultural significance, disrupting community identity and the use of valued public spaces. Repeated storm surge events may also accelerate shoreline changes and contribute to the long-term loss of natural and cultural resources along Aguada's coastline.

4.11.2.5 Future Conditions

Storm surge poses a significant long-term threat to Aguada's coastal communities, public infrastructure, transportation assets, recreational facilities, and natural resources. Future impacts may be exacerbated by continued coastal development in vulnerable areas, shoreline erosion, and the increasing exposure of infrastructure located near the coast.

During a storm surge event, elevated water levels and wave action can inundate low-lying coastal areas, causing damage to residential neighborhoods, municipal infrastructure, coastal roads, public facilities, and tourism-related businesses. Access routes may become impassable, limiting emergency response and evacuation operations and increasing risks to public safety.

Aguada's coastline is also susceptible to coastal erosion and shoreline retreat. Storm surge can accelerate these processes by removing beach sediments, undermining coastal infrastructure, and increasing damage to roads and public access areas near the shoreline. Repeated storm surge events may result in higher maintenance costs and increased vulnerability of coastal assets over time.

Storm surge may also adversely affect environmentally sensitive coastal areas by causing habitat degradation, saltwater intrusion, and sediment displacement. These impacts can reduce the effectiveness of natural protective features and increase the municipality's susceptibility to future coastal hazards.

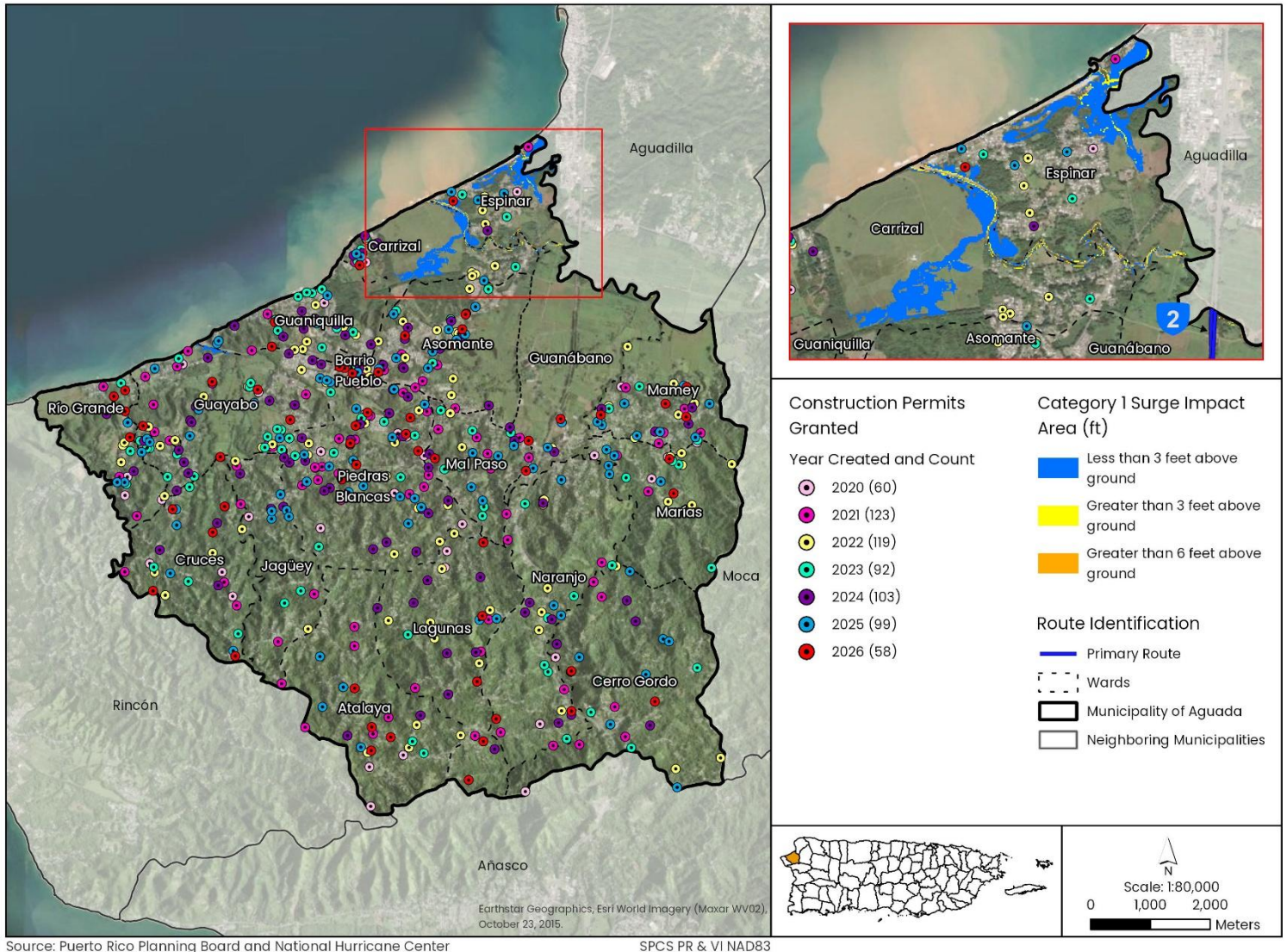
Future conditions may require continued implementation of mitigation measures such as the protection and restoration of natural coastal buffers, shoreline stabilization projects, coastal floodplain management, and the improvement of evacuation routes serving vulnerable coastal communities. Given Aguada's coastal setting, storm surge will remain a significant hazard with the potential to affect public safety, economic activity, natural resources, and critical infrastructure throughout the municipality.

Maps 50 and 51 show the construction permits approved between 2019 and 2026 in relation to the Category 1 and Category 5 storm surge impact areas, respectively. The maps indicate that numerous construction permits have been issued throughout the municipality during this period. Within both storm surge scenarios, development activity is visible in portions of the northern coastal area, particularly near the Carrizal,

Espinar, and Guaniquilla sectors. The Category 5 storm surge impact area extends farther inland than the Category 1 impact area; however, both maps show the presence of permitted development within or adjacent to the mapped storm surge zones.

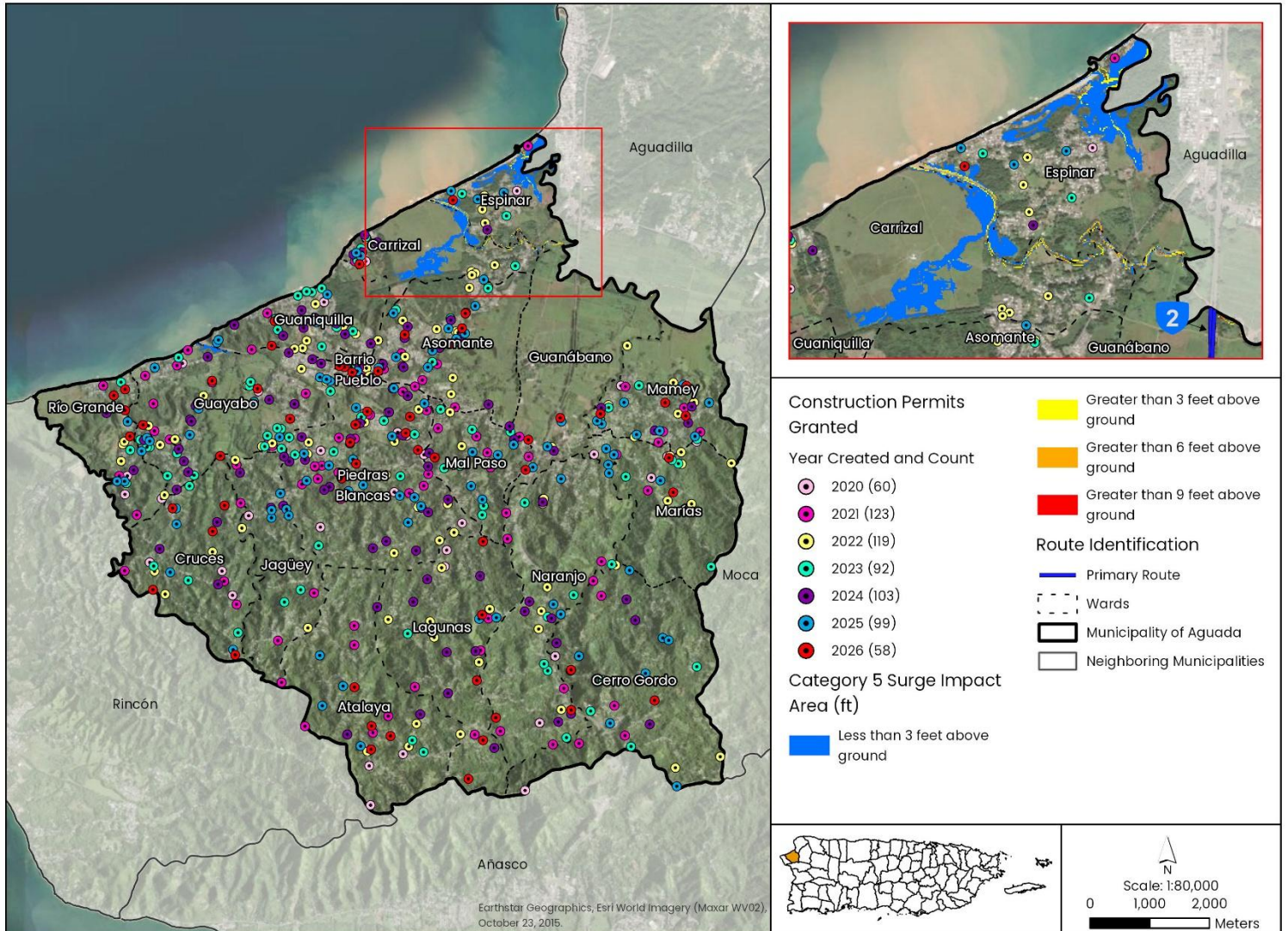
Map 50. Storm Surge: Recent Development Exposure Category 1 Surge

STORM SURGE: RECENT DEVELOPMENT EXPOSURE CATEGORY 1 SURGE



Map 51. Storm Surge: Recent Development Exposure Category 5 Surge

STORM SURGE: RECENT DEVELOPMENT EXPOSURE CATEGORY 5 SURGE



4.12 Extreme Heat

4.12.1 Description (B1-a)

There is no universally accepted definition for extreme heat or heat waves. For the purposes of this Plan, the definition adopted by the Department of Homeland Security (DHS) is used. It is defined as a prolonged period of 48 to 72 hours of intense heat and humidity, with temperatures above 90 °F. Under these conditions, evaporation is reduced and the body is forced to make a significant effort to maintain its normal temperature, which has caused the death of many people in attempts to stabilize physically. In general, extreme heat represents the highest rate of deaths among weather-related hazards.

A study titled Heat Risk Perception and Vulnerability in Puerto Rico: Insights for Climate Adaptation in the Caribbean, published in the academic journal International Journal of Environmental Research and Public Health, analyzes how Puerto Rico residents perceive health risks associated with extreme heat and how these perceptions relate to vulnerability and protective behaviors during extreme heat events that occurred in the summer of 2020 (Guzmán-Colon, Guido, Amaya-Ardilla, Cabrera-Rivera, & Méndez-Lázaro, 2025). The research was conducted through a cross-sectional telephone survey of 500 adults in metropolitan and non-metropolitan areas. This study defined the metropolitan area as the municipalities of Aguada, Carolina, Cataño, Toa Baja, and Trujillo Alto. The non-metropolitan zone consists of the remaining municipalities of Puerto Rico.

The questionnaire included sociodemographic variables, health status, prior heat exposure, risk perception, and mitigation strategies. Statistical analysis employed chi-square tests and multinomial and logistic regression models.

The results reveal that, although most participants expressed concern about climate change and high temperatures, less than half perceived heat as a high health risk, and only one-fourth considered it likely to suffer a heat-related illness in the next five years. Risk perception was significantly higher among men, people aged 50 to 64, the unemployed, individuals with fair health, multiple chronic conditions, and those who had experienced heat-related symptoms. In contrast, older adults (65+) reported low levels of risk perception despite their high vulnerability.

Forty-four percent (44%) of respondents indicated having suffered heat-related

symptoms during the summer, and 68% reported nighttime thermal discomfort, a factor closely linked to health problems. The most common strategies to mitigate heat were the use of fans (84%) and air conditioning (64%), although economic limitations and instability of the electrical system reduced their effectiveness. Regional differences were also notable: residents in non-metropolitan areas showed greater risk perception than those in metropolitan zones.

The study concludes that there is a significant gap between actual vulnerability and risk perception, especially among older adults. It recommends strengthening risk communication targeted at vulnerable groups, addressing nighttime heat exposure, and improving electrical infrastructure to ensure equitable access to cooling systems. Proposed solutions include decentralized energy systems, cooling centers with backup power, and passive designs that reduce electrical dependence, thus contributing to community resilience in the face of increasing extreme heat events.

4.12.1.1 Affected Area (B1-b)

Extreme heat events can impact the entire municipality, particularly in urbanized areas where the heat island effect may occur. Based on previously presented information, adverse climate effects have been observed, including severe droughts, increased frequency of strong wind events and flooding, higher heat index levels, among others. Due to the municipality's geography and location, the entire region is highly susceptible to extreme heat conditions.

Urban heat islands refer to urbanized areas where structures such as buildings, roads, and other infrastructure absorb and emit the sun's heat more than natural landscapes such as forests and water bodies. Daytime temperatures in urban areas are about 1–7 °F higher than temperatures in outlying areas; nighttime temperatures are about 2–5 °F higher (EPA, 2025).

Heat islands develop due to a combination of factors:

- Loss of Natural Landscapes – Urban areas often replace trees, vegetation, and water bodies—natural elements that cool the air through shade, transpiration, and evaporation—with hard, dry surfaces like roads, rooftops, and parking lots. These surfaces provide little shade or moisture, leading to higher temperatures.
- Properties of Urban Materials – Common construction materials such as asphalt and concrete absorb and retain more heat than natural surfaces. They

reflect less solar energy and release heat slowly, causing temperatures to remain elevated, especially after sunset.

- Urban Design and Geometry – The layout of buildings affects airflow and heat retention. Dense developments with narrow streets and tall structures create “urban canyons” that trap heat and block cooling winds, turning buildings into thermal masses that release heat gradually.
- Human-Generated Heat – Activities such as transportation, industrial operations, and air conditioning add waste heat to the environment, intensifying the heat island effect.
- Weather and Geographic Conditions – Clear, calm weather amplifies heat islands by maximizing solar energy absorption and limiting heat dispersion. Conversely, wind and cloud cover help reduce the effect. Geographic features like mountains can also influence wind patterns, either blocking cooling breezes or channeling heat through urban areas (EPA, 2025).

According to Aguada's land use characteristics and Territorial Plan, urban development is concentrated within the urban center and other developed corridors, while a substantial portion of the municipality remains rural, agricultural, or consists of natural lands. Although the urban heat island effect is generally more pronounced in developed areas with a higher concentration of buildings, paved surfaces, and limited vegetation, extreme heat can affect the entire municipality. Given Aguada's geographic location and climatic conditions, all residents may be exposed to periods of elevated temperatures, with potentially greater impacts on vulnerable populations and areas with limited shade or cooling resources.

4.12.1.2 Risk Magnitude (B1-c)

Local NWS offices often work with community agencies to decide when heat alerts should be issued. Because the United States is so geographically and culturally diverse, heat tolerance varies by region. For example, residents of Puerto Rico are generally more accustomed to temperatures above 90°F than those living in Alaska.

Nevertheless, the NWS uses the following standard alerts (NWS, n.d.):

- Excessive Heat Warning – Issued 12 hours before dangerous heat conditions are expected. This occurs when the heat index is forecast to reach 105°F or higher for more than three hours over two consecutive days, or 115°F or higher for any period.

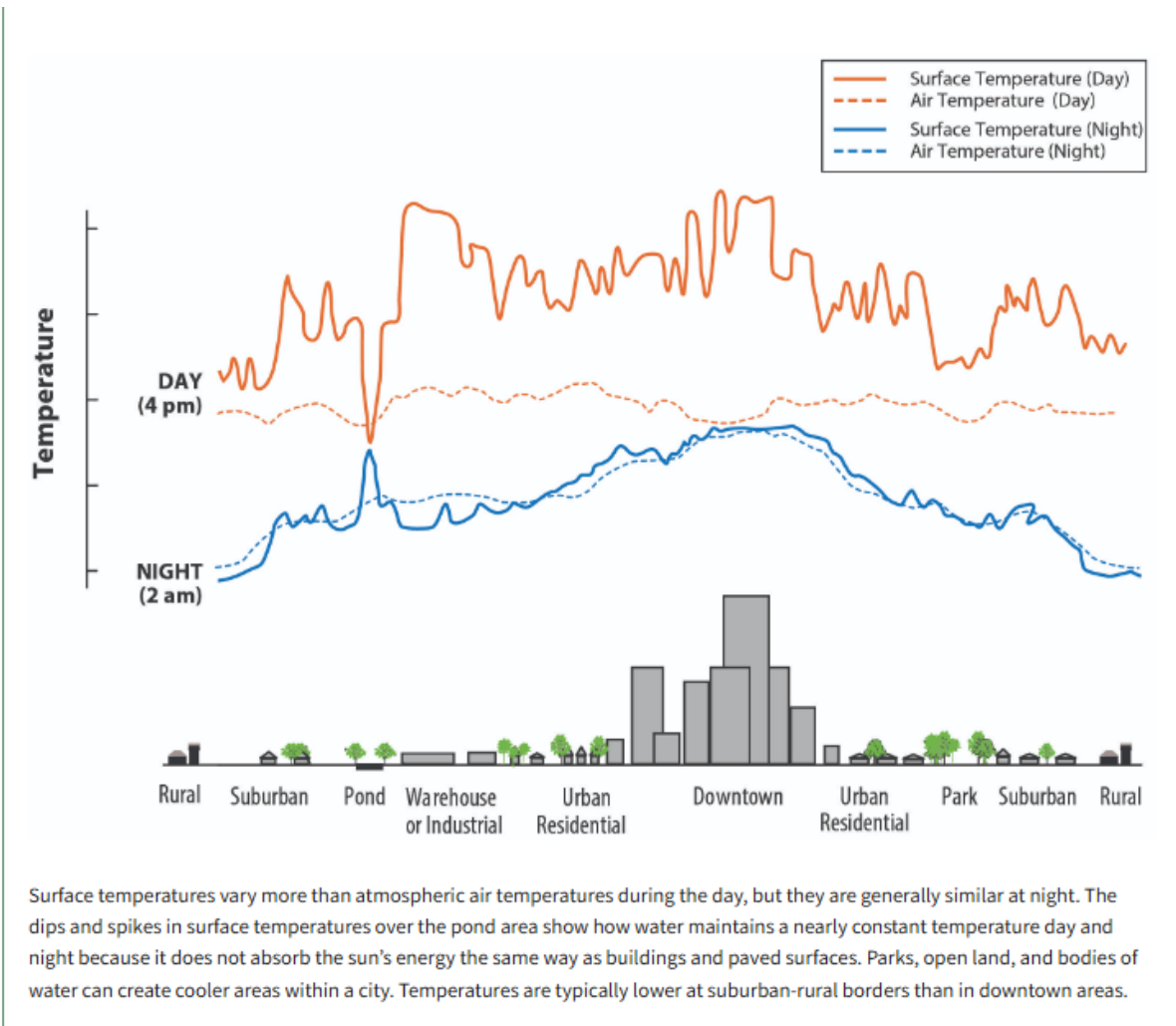
- Excessive Heat Watch – Issued when an extreme heat event is possible within the next 24 to 72 hours.
- Heat Advisory – Issued 12 hours before conditions where the heat index is at least 105°F but less than 115°F for three consecutive days.
- Extreme Heat Outlook – Issued when there is potential for extreme heat within the next three to seven days, providing advance notice for those who need extra time to prepare.

It must be emphasized that Urban Heat islands (UHI) phenomena can occur regardless of whether there is an extreme heat warning event. UHI is a relative temperature difference between urban and surrounding rural areas caused by factors like heat-absorbing surfaces, lack of vegetation, and human activities. It exists year-round, even during mild or cool weather, because cities consistently retain more heat than natural landscapes. Extreme heat events can amplify UHI, making UHI effects more dangerous, but UHI does not require extreme heat to form—it simply means urban areas are warmer than their surroundings under similar conditions.

UHIs are typically assessed by comparing temperatures in urban areas to those in surrounding regions. Even within a city, temperatures can vary significantly. Some neighborhoods are hotter due to dense concentrations of heat-absorbing surfaces like buildings and pavements, while areas with trees and greenery remain cooler. These variations create what are known as intra-urban heat islands. In diagrams illustrating this effect, urban parks, ponds, and residential zones generally appear cooler than central downtown districts.

The following diagram, taken from an EPA website, shows a diagram of how a heat island effect behaves in temperature.

Figure 23. Heat Island Effect Diagram (EPA, 2025)



Source: EPA

4.12.1.3 Past Events (B1-d)

Méndez Lázaro et al. (2015) identified several years in which extreme heat temperatures were recorded in the San Juan metropolitan area. According to their findings, periods of extreme heat occurred in 1983, 1995, 2012, and 2013. Notably, the summer of 2012 was the hottest in a century, with 42 days of extreme temperature values. During June, July, and August, the maximum heat index reached 98.06° F, 98.96° F, and 102.02° F, respectively (Méndez Lázaro et al., 2015).

4.12.1.4 Future event probabilities (B1-e)

Official NOAA assessments in the 2018 Puerto Rico and U.S. Virgin Islands State Climate Summary report an increase in both average temperature ($\approx 1.5^{\circ}\text{F}$ since 1950) and the frequency of extreme heat events (NOAA, 2022). Additionally, climate projections from CMIP6 (via the World Bank's Climate Change Knowledge Portal) show steady rises in summer and annual maximum temperatures for Puerto Rico, further indicating elevated future risk for heat waves (World Bank, n.d.).

4.12.2 Risk Analysis (B2-a, B2-b)

4.12.2.1 Estimated Losses

Extreme Heat primarily causes material and system stress rather than immediate structural failure. For example:

- Roads and Pavements: Asphalt can soften and deform under prolonged high temperatures, leading to rutting and surface damage (Highways Industry, n.d.) (EPA, 2012).
- Rail Systems: Steel tracks expand in extreme heat, which can cause buckling and derailment risks (USDOT – FRA, 2013).
- Power Infrastructure: Electrical grids experience higher loads from air conditioning demand, and transformers or cables can overheat, reducing efficiency or causing outages.
- Building Materials: Expansion and contraction of concrete, steel, and glass can lead to cracks or joint failures over time. Roofing materials may degrade faster under intense heat.
- Cooling Systems: HVAC systems work harder, increasing energy consumption and risk of failure, which can compromise indoor comfort and safety.

While heat waves rarely cause buildings to collapse, they accelerate wear and tear, increase maintenance costs, and can lead to system failures that disrupt essential services. As of now the municipality does not have a method to calculate losses from extreme heat events.

4.12.2.2 Lifelines and Critical Infrastructure

Extreme heat poses systemic risks across energy, transportation, and communications systems, creating compound failures precisely when demand for

services peaks. In Energy Lifeline, high temperatures drive sharp increases in electricity demand for cooling while simultaneously decreasing generation and delivery efficiency. Thermoelectric plants may be forced to curtail output when cooling water is too warm, solar panels produce less electricity at elevated module temperatures, and transmission lines lose carrying capacity as conductors heat and sag—conditions that heighten the likelihood of voltage drops and blackouts during heat waves (Jessen, 2025). The combination of record cooling loads and diminished supply underscores a growing “peak risk” problem for grids that were not designed for today’s heat extremes (Jessen, 2025) (American Society of Civil Engineers, 2024).

Similarly, the Transportation Lifeline is similarly vulnerable. Prolonged high surface temperatures soften asphalt, accelerating rutting and deformation; steel rails thermally expand and can buckle, prompting heat-related slow orders that disrupt service; and catenary or other overhead lines can sag in the heat, further constraining operations. Airports face dual constraints: runway pavements can deform under extreme heat, and reduced air density on hot days impairs aircraft performance, affecting takeoff weight and scheduling. These effects are now commonly observed across U.S. systems during sustained heat events, requiring operational restrictions and emergency maintenance that ripple through supply chains and passenger mobility (American Society of Civil Engineers, 2024).

Communication Lifeline also faces mounting heat stress. Data centers, switching facilities, and network nodes rely on continuous cooling; overheating elevates outage risks and can degrade equipment lifespans. Heat-related disruptions to power supply and localized microclimate conditions compound these risks, with cascading impacts across other lifeline sectors that depend on connectivity for operations and emergency response. Federal assessments underscore that extreme weather—including extreme heat—can interrupt fiber networks, degrade wireless performance, and limit access to data centers, affecting each of the other critical infrastructure sectors and complicating disaster response coordination (Public-Private Analytic Exchange Program, 2025).

Overall, extreme heat acts as a stress multiplier: it pushes materials beyond design thresholds, reduces equipment efficiency, and narrows operational safety margins, all while increasing demand for services. The evidence from engineering organizations and energy market observers indicates that without targeted adaptation—such as heat-resilient design standards, strategic grid reinforcement, enhanced thermal management for digital infrastructure, and heat-aware operations—systems will face more frequent service disruptions and higher lifecycle costs as heat events intensify

(American Society of Civil Engineers, 2024).

4.12.2.3 Social Vulnerabilities

A recent academic study examines the relationship between heat stress and mortality in Puerto Rico (Méndez – Lázaro, et al., 2025). Researchers analyzed hourly 2-meter air temperature data from ERA5 reanalysis for 2015–2020 and derived daily minimum, maximum, and mean values to calculate two heat stress indices: the Heat Index (HI) and the Universal Thermal Climate Index (UTCI). Findings show that extreme heat conditions are common for eight months of the year, with August and September being the hottest months, and that urban heat island effects exacerbate exposure in metropolitan areas. (Méndez – Lázaro, et al., 2025) Mortality risk increased significantly on days with high heat stress: deaths were 23% higher in the highest HI tertile and 47% higher in the highest UTCI tertile compared to the lowest. Cardiovascular and cerebrovascular diseases, heart failure, and respiratory conditions were among the leading causes of death associated with heat stress. The study highlights Puerto Rico's socio-economic vulnerabilities, aging population, and limited infrastructure amplifying health risks during extreme heat events (Méndez – Lázaro, et al., 2025).

4.12.2.4 Natural and Cultural Resources

Extreme heat, specifically Urban Heat Islands can pose the following impacts on the natural resources:

- Increased Energy Consumption – Heat islands increase electricity demand for air conditioning and peak energy demand. Increased electricity demand for air conditioning ranges from 1–9% for each 2°F increase in temperature, with the highest increase in countries where most buildings have air conditioning, such as the United States.[3] This increased demand contributes to higher electricity expenses. Peak demand generally occurs on exceptionally hot afternoons, when offices and homes are running air-conditioning systems, lights, and appliances. This increased demand can overload systems and require a utility to institute controlled brownouts or blackouts to avoid power outages.
- Elevated Emissions of Air Pollutants – To meet electricity needs, utility companies typically rely on fossil fuel power plants as a power source. Increased use of fossil fuels increases emissions of air-borne pollutants, such as carbon dioxide, which can have health concerns, especially in people living with respiratory diseases.

- Compromised Human Health and Comfort – Hot weather events contribute to heat-related deaths and heat-related illnesses. Areas experiencing heat islands further contribute to higher daytime temperatures and reduced nighttime cooling. Heat is of greatest concern for groups such as older adults, young children, populations with low-income, people who work outdoors, and people with chronic health conditions, disabilities, mobility constraints, or taking certain medications. From 2004 to 2018 the Centers for Disease Control and Prevention recorded an average of 702 heat deaths per year.

Impaired Water Quality – High temperatures of pavement and rooftop surfaces can heat stormwater runoff, which drains into storm sewers. This runoff raises water temperatures as it is released into streams, rivers, ponds, and lakes. Water temperature affects the metabolism and reproduction of many aquatic species.

Rapid temperature changes can also be stressful, and even fatal, to aquatic life. One study found that urban streams have more frequent temperature surges than streams in forested areas. Temperature surges in urban streams were as much as 18°F higher due to heated runoff from urban areas, higher discharge volumes due to impervious surfaces, and warmer baseline stream temperatures (EPA, 2025).

4.12.2.5 Future Conditions

The approved construction permits maps (Maps 10 and 11) show that many of the recent developments in Aguada are in the already built-up area of the city. This means that the urban heat island effect will continue to be present in the municipality in the near future.

Most of Aguada's settlements, being predominantly rural municipalities, are spread-out throughout existing, or past, agrarian communities. While the potential for UHI is relatively low when compared to larger, denser, urban developments, design decisions regarding the materials, design, placement and orientation of buildings can create or exacerbate extreme heat conditions in individual buildings.

4.13 Drought

4.13.1 Description (B1-a)

Drought is described as a temporary irregularity in rainfall or natural water flow, where a prolonged lack of precipitation leads to a significant hydrological imbalance. This condition may or may not result in interruptions to regular drinking water service, crop failures, and adverse effects on wildlife and vegetation. The severity of a drought is determined by the level of moisture deficiency, its duration, and the geographic extent of the affected area (Colón, 2009).

Drought represents one of the most complex climatological risks and one of the most severe events (DRNA, 2016). Drought is the result of a natural reduction in the expected amount of precipitation over a prolonged period, usually a season or longer. High temperatures, strong winds, and low humidity levels can exacerbate the effects of drought in areas where they are already prevalent. Likewise, drought can lead to severe wildfires (FEMA, 1997). Human actions and the demands they place on water resources can accelerate drought-related impacts. Droughts occur in different forms across the island, meaning that some regions may experience greater impact while others remain normal.

According to FEMA there are four types of droughts (FEMA, 1997):

Table 46. Types of Droughts

Meteorological Drought	A period characterized by a significant deficiency in precipitation compared to normal conditions over a specific timeframe (e.g., monthly, seasonal, yearly)
Agricultural Drought	Occurs when soil moisture becomes insufficient to support crops or livestock needs, typically following meteorological drought.
Hydrological Drought	Defined by reduced water levels in streams, rivers, reservoirs, and groundwater systems, often lagging behind meteorological drought
Socioeconomic Drought	Reflects the impact on human systems and the economy, arising when water supply shortages—due to any form of drought—fail to meet societal demand for water and other resources

In 1999, the Federal Drought Monitor program was implemented. This program is a tool that publishes data and maps on drought conditions in the United States, including Puerto Rico and Hawaii. This system integrates information from various agencies, such as NOAA, the United States Department of Agriculture (USDA), and the National Drought Mitigation Center at the University of Nebraska–Lincoln. In addition, the

monitor has developed standardized indicators that allow drought categories to be classified at the national level, providing a uniform reference for risk assessment and management.

The short-term drought indicator focuses on precipitation over 1–3 months. The long-term drought indicator focuses on a period of 6–60 months. Additional indices used, especially during the growing season, include the “USDA/NASS Topsoil Moisture,” the Keetch-Byram Drought Index (KBDI), and NOAA/NESDIS satellite vegetation health indices. Other indicators include groundwater levels, reservoir capacity, and pasture conditions.

In Puerto Rico, the Puerto Rico Aqueduct and Sewer Authority (PRASA), the Puerto Rico Electric Power Authority (PREPA), and the Department of Natural and Environmental Resources (DNER) are responsible for constantly monitoring the dams and reservoirs used for potable water supply. Once critical levels are reached, the first strategy adopted at the supply system level is reducing water pressure. If adequate levels are not restored, water rationing begins. This is implemented in phases lasting 12 hours and, in extreme cases, up to 48 hours. The affected area is divided into sectors, and the different rationing phases of a given duration are initially implemented locally, usually in municipalities with the highest consumption. In extreme circumstances, several municipalities and entire regions may be affected.

4.13.1.1 Affected Area

Aguada’s administrative boundary is uniquely influenced by its topography, as it largely coincides with the natural limits of the watersheds formed by the surrounding mountainous terrain. The municipality’s steep ridges and enclosed valleys define drainage patterns in such a way that most surface water flow originates and remains within its own territory, rather than receiving significant inflows from external watersheds. While this configuration helps contain runoff during rainfall events, it also creates heightened vulnerability during periods of drought. Because Aguada depends primarily on the precipitation that falls within its boundaries, prolonged dry conditions can significantly reduce water availability, with limited opportunity to offset shortages through inflows from neighboring regions. This makes localized droughts particularly critical, as water supply becomes directly tied to internal climatic conditions and the capacity of local watersheds to sustain demand.

4.13.1.2 Risk Magnitude (B1-c)

Drought is a slow-onset hazard, but over time, it can have highly detrimental effects on crops, municipal water supplies, recreational uses, and wildlife. If drought conditions persist for several years, the direct and indirect economic impact can be significant. Drought can also potentially provide favorable conditions for another hazard to occur, wildfire.

The National Drought Monitoring Center uses the following categories to describe the magnitude of drought conditions (US Drought Monitor, 2025).

Table 47. US Drought Monitor Categories

Category	Description	Typical Impacts
None	Normal/Wet Conditions	No drought impacts
D0 – Abnormally Dry	Early signs of dryness may slow planting, affect surface water	Short-term dryness; minor stress
D1 – Moderate Drought	Noticeable soil moisture depletion; low water; voluntary restrictions	Crop stress; reduced streamflow
D2 – Severe Drought	Common water shortages; likely crop/pasture losses	Mandatory restrictions possible
D3 – Extreme Drought	Major crop/pasture losses; widespread restrictions	Fire bans; severe water stress
D4 – Exceptional Drought	Exceptional and widespread losses; water emergencies	Emergency measures; critical impacts

4.13.1.3 Past Events (B1-d)

Puerto Rico has a humid tropical climate characterized by two well-defined seasons: a rainy season, which extends from May to November, and a dry season, which runs from December to April. The eastern and western interior regions record the highest annual rainfall, while the northern zone receives significantly more rain than the south.

USGS identified that major drought conditions have occur in 1967 – 1969, 1974, 1994, 1994, 1997, 2001–2002 and 2013 –2016 (USGS, 2014), (DNER, 2016). According to historical

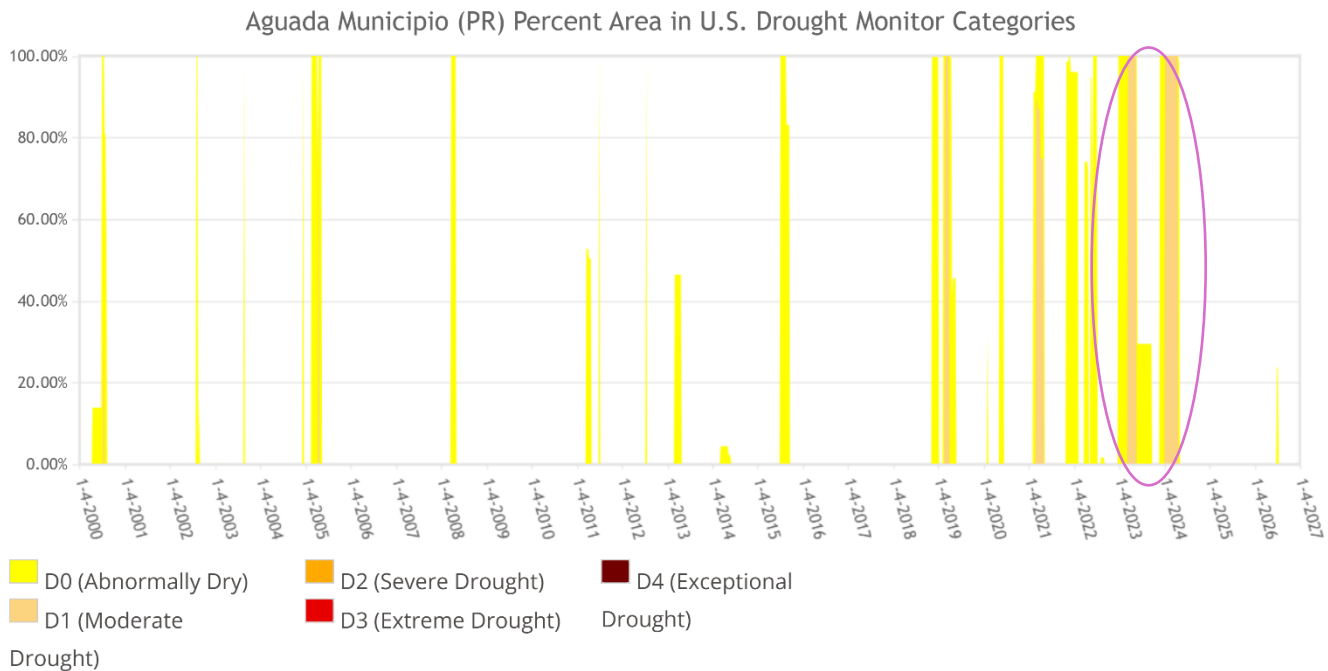
records the federal government has activated its resources to deal with drought conditions;

- Puerto Rico Extreme Drought Conditions (DR-170-PR) – Date of Declaration May 26, 1964
- Puerto Rico Impact of Drought (EM-3002-PR) – Date of Declaration August 29, 1974

During the rainy season, precipitation mainly comes from local convection processes, orographic effects, tropical waves, and cyclones. In contrast, rainfall during the dry season is mostly associated with the influence of cold fronts and troughs (CEACC, 2024).

Figure 24 shows the data captured by US Drought Monitor Categories for the period of January 2020 to January 2026 (US Drought Monitor, 2025) for Puerto Rico's entire territory. The graph measures the occurrence, duration, territorial extent and intensity of droughts in Puerto Rico. Intensity is measured with a color gradient ranging between yellow (D0 (abnormally Dry in the legend) as being the lowest intensity and the dark red (D4 Exceptional Drought) representing the highest level of drought. Duration is measured through the width of the data, expressed along the lower axis of the graph. Territorial extent is represented on the horizontal axis of the graph, the higher an event reaches the more Puerto Rico's territory it covers. Occurrence is measured by combining all the other variables and locating them within the graph. The municipality of Aguada experienced recurring drought conditions throughout the study period, with Abnormally Dry (D0) conditions occurring most frequently. The highlighted period shows a higher recurrence of Moderate Drought (D1) conditions between 2023 and 2024, accompanied by brief episodes of Severe Drought (D2), indicating an increase in drought intensity during that timeframe.

Figure 24. Municipality's Percent Area in U.S. Drought Monitor Categories



From the U.S. Drought Monitor website, <https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx>, 9-11-2026



Source US Drought Monitor

From the graph we may appreciate a sustained trend of increased occurrence, duration and intensity of droughts in Puerto Rico that began as early as 2010 and solidified by 2014. Between 2015–2017, Puerto Rico experienced the most intense period of drought in recent years, with more than 80% of the Island’s territory experiencing at least Abnormally Dry levels while at least 20% of the territory experienced Extreme Drought. The 2017 Hurricane season brought historic volume of precipitation, which explains the brief reduction in drought between 2017–2019. From 2017–2024, Puerto Rico experienced an extended period of drought in the vast majority of its territory.

4.13.1.4 Future event probabilities (B1-e)

USGS reports that in Puerto Rico, drought has an occurrence of 15 of 18 years (USGS, 2016), (USGS, 2014). Recent scientific data shows that the Caribbean region faces increased vulnerability to drought hazards. (USGCRP, 2018). The probability of drought occurrence is difficult to forecast or foresee in a long-term perspective. Though as figure 24 shows, moderate droughts periods have become more prevalent since 2019.

4.13.2 Risk Analysis (B2-a, B2-b)

If drought results in potable water rationing, the municipality could experience economic losses to the extent that services are immediately affected by the partial or total closure of schools, businesses, industrial areas, and public and private offices.

The potential economic impact of a prolonged drought would arise from the need to mobilize the municipality to meet the basic needs of its population during the emergency period. This cost is associated with mobilizing resources such as personnel and equipment for the distribution of water to communities and municipal facilities. However, the municipality has not been able to quantify the economic impact of this expense, nor the impact on agriculture, due to a lack of information. Since drought is a hazard that does not directly affect structures, no dollar estimate of structural losses is generated.

Drought conditions in Aguada can significantly impact the agricultural industry by reducing water availability for irrigation and stressing crops during critical growing periods. Prolonged dry conditions can quickly lead to soil moisture deficits, lower crop yields, and in severe cases, total crop failure. In addition, reduced water supply can affect livestock and increase production costs, as farmers may need to rely on alternative water sources. These combined effects threaten the economic stability of agricultural operations and the overall food supply within the municipality.

4.13.2.1 *Estimated Losses*

Documenting the fiscal impact of a drought is a complex process due to the wide range of ways this climate event affects society (DNER, 2015). For example, during the 2015 drought a potable water rationing plan was implemented for the San Juan Metropolitan Area (SJMA) of which Aguada is part of.

Another way to document the losses caused by drought period is by looking at the impact on the agricultural sector. The Puerto Rico Department of Agriculture reported that the 2015 drought had a net cost of \$14,000,000.00 impact on the agricultural sectors.

4.13.2.2 *Lifelines and Critical Infrastructure*

Drought can place significant strain on critical infrastructure by reducing water

availability for municipal systems, often leading to rationing measures and service interruptions. Extended water shortages can disrupt essential operations in schools, hospitals, and businesses, resulting in economic losses and reduced access to public services. Energy infrastructure may also be affected, particularly where hydroelectric generation declines due to low reservoir levels, increasing reliance on more expensive or less sustainable energy sources. Transportation systems can experience indirect impacts, such as road damage caused by soil shrinkage and heightened wildfire risk along highways. Emergency response and communication services may face additional challenges when limited water supplies constrain cooling systems and firefighting capabilities. Collectively, drought conditions can trigger cascading impacts across interconnected infrastructure systems, increasing vulnerabilities and underscoring the need for coordinated mitigation and response strategies.

As noted above, drought events that require potable water rationing can lead to economic losses for the municipality by disrupting normal government operations. Partial or complete closures of schools, businesses, industrial zones, and public or private offices may occur when water availability is reduced. These impacts primarily affect the day-to-day functioning of municipal assets, as the services they provide are directly limited by water shortages or service interruptions. As droughts become more frequent or prolonged, their cumulative effects on operations are likely to intensify. However, while drought significantly affects service delivery and operational capacity, it does not directly damage the municipality's critical facilities and physical assets.

4.13.2.3 Social Vulnerabilities

As mentioned in Section 3.4.2, the estimated vulnerable population of Aguada is 40.35%. If the pattern of recurring drought conditions observed in recent years continues, the vulnerable population of Aguada will continue to face major challenges regarding access to potable water. Communities may experience a decrease in water availability, which is essential for agricultural and commercial activities, as well as for personal consumption by residents. Drought conditions can also affect public health and quality of life, resulting in physical and mental stress, social discomfort, and increased risks associated with dehydration and other health-related impacts. Since drought conditions can affect water availability regardless of whether precipitation deficits occur directly within the municipality, it is recommended that the municipal administration consider the entire population of Aguada as exposed to this hazard.

4.13.2.4 Natural and Cultural Resources

When a region experiences prolonged and cumulative periods of little or no rainfall, a drought begins. This natural hazard has adverse effects on biodiversity and water supplies. For instance, a precipitation deficit lowers water levels in bodies of water, including mangroves, impacting the region's flora and fauna. Damage to vegetation directly affects animal habitats, creating an imbalance in food availability for wildlife.

Agriculture in the area is also severely affected due to the lack of water. When rainfall is significantly below normal levels, it causes severe hydrological imbalances that negatively affect land productivity systems. Similarly, crop growth and harvests decline, along with the availability and quality of drinking water. Drought can also lead to ecosystem degradation, loss of biodiversity and species, wind erosion, and increased wildfire risk.

4.13.2.5 Future Conditions

Over the long term, drought-related challenges are expected to intensify as rainfall patterns continue to vary. These variations may result in droughts that are more severe, longer in duration, and wider in geographic extent than those experienced historically, thereby increasing vulnerability among affected populations.

Overall population trends in the Municipality of Aguada indicate a general decline at the neighborhood level. However, the population aged 65 and older has increased (see Section 3.4), representing a particularly vulnerable segment of the community. The growing proportion of older adults requires special consideration in drought planning due to heightened sensitivity to water shortages, health impacts, and service disruptions.

Future land development also plays a critical role in drought vulnerability. Approving projects near sinkholes or developments that rely on septic systems increases the risk of groundwater contamination, which becomes especially problematic during drought conditions when alternative water sources are limited. Additionally, soil surface impermeabilization and the obstruction or filling of sinkholes reduce natural aquifer recharge by increasing surface runoff. These factors further diminish groundwater availability, limiting its viability as a supplemental water source during drought events.

4.14 Wildfire (E1-a)

4.14.1 Description (B1-a)

Wildfires are uncontrolled fires that spread through vegetation, posing serious threats to structures, human health, and natural ecosystems. These events often begin unnoticed and can spread rapidly, producing dense smoke that affects nearby communities. While wildfires may occur at any time of year, they are most common during periods of low rainfall, when grasses, leaves, and other fine fuels become dry and highly combustible.

In 2021, the Puerto Rico Department of Natural and Environmental Resources published its Forest Action Plan (DNER, 2021). The Plan discusses overall trends, issues and objectives for the management of forest resources. Wildfires are among the challenges discussed in the document. The Plan argues that wildfire management is a pressing issue at both local and global levels due to the complex interactions among human activity, fire dynamics, and natural landscapes. While research has established that fire influences ecosystem structure and function, its effects on ecosystem services remain uncertain because of interrelated factors such as land cover changes, invasive species, and climate change (Gould, 2008).

A clear understanding of the ecological and social impacts of wildfire in Puerto Rico's natural ecosystems is essential for guiding effective conservation and management strategies. Prevention efforts must extend to private forest owners and the public, as most fires on the island are human caused (Gould, 2008). Historically, fire monitoring and research in the region have received limited attention. Currently, fires occur predominantly in dry forest zones, where the risk is highest. However, climate change, prolonged droughts, and human-induced landscape fragmentation could expand fire-prone conditions into moist and wet tropical forests, as well as into areas traditionally unaffected by fire (Gould, 2008).

4.14.1.1 Risk Magnitude

The United States Forest Service main classification for fire types (USFS, n.d.) are;

- **Ground Fire** – Fire that burns within the organic material below the litter layer, mostly by smoldering combustion. It typically occurs in duff, peat, dead moss and lichens, and punky wood are typically ground fire. Ground fires mainly

growing vegetation such as grasslands, shrubs, and tree bases. Depending on environmental factors (vegetation composition and density, slope orientation and steepness, wind speed, among others), these fires can vary in intensity but generally release less thermal energy than fires that spread through tree canopies.

- **Crown Fires** – A fire that burns in the crowns of trees and shrubs usually ignited by a surface fire. Crown fires are common in coniferous forests and chaparral-type shrublands. In these types of fires, flames climb through lower branches until reaching the tree canopy. However, in some cases, its spread remains primarily surface-based, often because trees are sparse and their canopies are too far apart.
- **Surface Fire** – A fire that burns through leaf litter and other live or dead fuels located at or just above the ground, mostly by flaming combustion.

While FEMA follows a four-classification typology (FEMA, 1997):

- **Wildfires** – Fueled almost exclusively by natural vegetation. They typically occur in forests and national parks, where federal agencies are responsible for fire management and suppression.
- **Interface or Intermixed Fires** – Fires that occur in urban and/or wildland areas where vegetation and integrated surroundings provide the fuel.
- **Firestorms** – Events of such extreme intensity that effective suppression is virtually impossible. Firestorms occur under severe weather conditions and generally burn until conditions change, or available fuel is exhausted.
- **Intentional and Prescribed Burns** – Fires caused by human intervention and natural fires intentionally allowed to burn vegetation for management purposes.

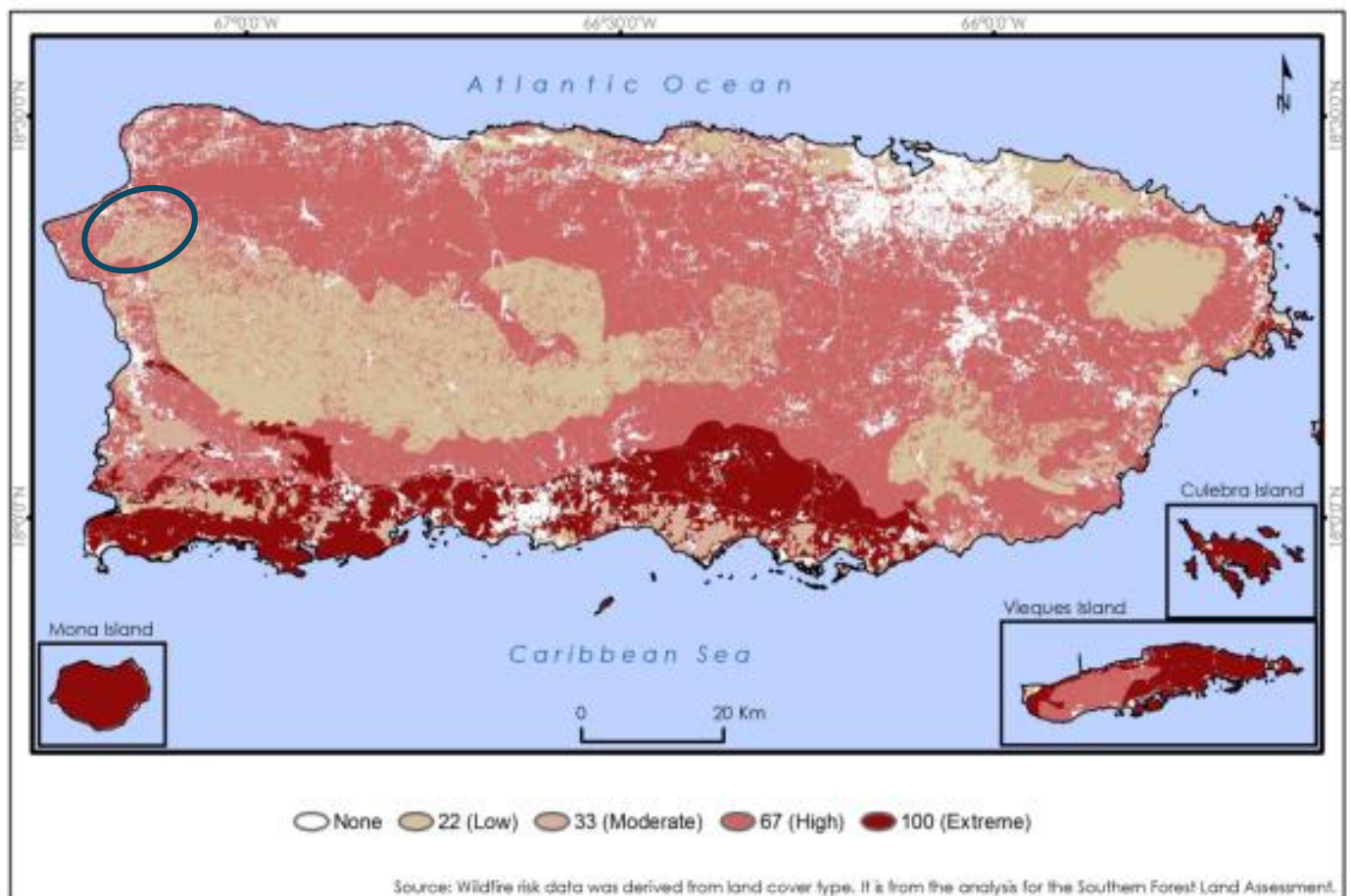
Another typology is the distinction between wildfires and wildland-urban interface (WUI) fires. Wildfires occur in areas with minimal development, except for infrastructure such as roads or power lines. WUI fires, on the other hand, involve situations when fire spreads into areas with structures or other human developments. In WUI fires, flames feed on both vegetation and structural elements of urban areas. The US Fire Administration defines WUI as the zone or area where human structures and developments meet or intermingle with wildland vegetation and fuels (US Fire Administration, 2025).

4.14.1.2 Affected Area (B1-b)

Figure 25 (DNER, 2021) illustrates the distribution of wildfire incidence across Puerto Rico, Vieques, and Culebra, as defined by the Southern Federal Land Assessment (SFLA). The figure reflects the current understanding of areas identified as fire-prone landscapes. Elevated wildfire occurrence in the southern coastal plains is largely attributed to the combined influence of human activity, the presence of dry and combustible fuels, and prevailing climatic conditions.

Within the municipality of Aguada, generally corresponding to the area highlighted by the blue oval, the landscape is predominantly characterized by low to moderate wildfire incidence. Most of the municipality falls within areas associated with lower wildfire occurrence compared to the southern region of Puerto Rico. While localized areas of moderate wildfire incidence may be present, the figure does not indicate extensive areas of high or extreme wildfire incidence within Aguada. Nevertheless, wildfire risk remains present and may increase during prolonged dry periods, particularly in vegetated areas susceptible to the accumulation of combustible fuels.

Figure 25. Overview of areas of Puerto Rico, Vieques and Culebra under different levels of wildfire



Wildfires are commonly associated with temperate climate regions such as California or parts of Canada; however, recent events in the State of Hawaii demonstrate that fast-moving and deadly wildfires can also occur in tropical, humid environments. The August 2023 Lahaina Fire was a catastrophic example, as rapidly advancing flames swept through densely developed neighborhoods and revealed significant shortcomings in early warning systems, evacuation planning, and overall community preparedness. Driven by dry vegetation, strong winds, and record drought conditions, the fire quickly spread to structures and overwhelmed emergency response capabilities. An independent investigation by the Fire Safety Research Institute found that limited infrastructure resilience, compromised communication systems, and insufficient interagency coordination greatly intensified the impacts of the disaster. As Puerto Rico faces comparable wildfire risks, particularly in the southern coastal plains, the Lahaina tragedy highlights the urgent need to strengthen fire detection capabilities, improve evacuation routes, and enhance public education on wildfire preparedness. Incorporating building codes that promote fire-resistant materials and defensible space around homes and critical facilities can significantly reduce structural damage during extreme wildfire events. The importance of integrated land-use and vegetation management is also evident, underscoring the need to limit development in wildland–urban interface areas and maintain appropriate vegetation buffers. Lessons learned from Lahaina emphasize that rapid, well-coordinated suppression efforts and resilient communication networks are critical to preventing wildfire escalation. Ultimately, increased cross-agency collaboration, emergency training, and proactive planning are essential to strengthening community resilience and reducing the likelihood of a similar wildfire catastrophe in Puerto Rico.

4.14.1.3 Past Events (B1-d)

Citing data from the Puerto Rico Firefighters Bureau (PRFB), The Puerto Rico Forest Action Plan states that a total of 7,099 wildland fires were reported across Puerto Rico between 2018 and 2020. The highest number of incidents occurred in 2020, with 5,077 recorded fires. The regions most affected were Ponce, Guayama, and Mayagüez (DNER, 2021).

Within the Department of Natural and Environmental Resources (DNER) Protected Natural Areas, fire incidence increased in 2019 compared to 2018. Notable affected sites included Guánica State Forest, Boquerón Wildlife Refuge, Punta Cuchara Natural Reserve, Caño Tiburones Natural Reserve, and Tortuguero Lagoon Natural Reserve. Most of these fires were linked to human activities, such as unattended campfires,

discarded cigarettes, intentional burning, improper waste burning, and poorly managed prescribed burns in pasturelands (DNER, 2021).

The high frequency of wildfires in Puerto Rico highlights the urgent need for targeted education and public outreach efforts to raise awareness. When combined with active land management and a landscape-scale conservation approach, these initiatives can help reduce the occurrence of fires and mitigate additional pressures on forest ecosystems.

The following table shows the wildfires reported in Aguada for 2024, which is the latest set of data completed by the Puerto Rico Fire Bureau.

Table 48. Registered Wildfires

Case Number	Discovery Date	Containment Date	Local Incident Id
BPR022724-703	2024-02-27 15:23:40.393000	2024-02-28 07:42:05.736000	-67.1342, 18.4486
PR032824-239	2024-03-28 09:19:06.413000	2024-03-28 11:59:33.272000	-67.16522, 18.3428
BPR032824-440	2024-03-28 11:59:58.341000	2024-03-28 20:17:09.343000	-67.1802, 18.3633
PR121124-560	2024-12-11 12:22:01.671000	2024-12-11 13:26:15.460000	-67.15355, 18.3909
BPR022924-446	2024-02-29 10:35:23.196000	2024-02-29 16:31:51.930000	-67.1802, 18.3633
BPR022924-914	2024-02-29 16:29:05.731000	2024-02-29 18:16:54.746000	-67.1802, 18.3633
PR031024-479	2024-03-10 12:33:35.372000	2024-03-10 15:15:08.436000	-67.16346, 18.3539
PR031024-621	2024-03-10 15:01:23.535000	2024-03-10 19:09:41.444000	-67.16088, 18.3478
BPR031124-671	2024-03-11 12:44:59.786000	2024-03-11 13:46:02.933000	-67.1802, 18.3633
PR032824-760	2024-03-28 16:33:48.623000	2024-03-28 17:29:54.391000	-67.16647, 18.3314
BPR033024-679	2024-03-30 16:13:06.006000	2024-03-30 19:24:31.182000	-67.1802, 18.3633
PR040224-1102	2024-04-02 23:38:41.010000	2024-04-03 02:15:50.527000	-67.14587, 18.3199
BPR040624-529	2024-04-06 12:33:13.448000	2024-04-06 14:06:36.396000	-67.1802, 18.3633

Case Number	Discovery Date	Containment Date	Local Incident Id
BPR040824-734	2024-04-08 14:20:33.817000	2024-04-09 08:58:51.988000	-67.1802, 18.3633
BPR040824-813	2024-04-08 15:11:05.109000	2024-04-08 17:00:43.546000	-67.1802, 18.3633
BPR011724-855	2024-01-17 16:48:01.238000	2024-01-17 18:16:42.895000	-67.1342, 18.4486
BPR011924-934	2024-01-19 17:38:45.254000	2024-01-19 18:00:59.294000	-67.1802, 18.3633
PR012324-700	2024-01-23 13:48:48.133000	2024-01-23 15:05:01.556000	-67.15153, 18.3549
BPR012724-746	2024-01-27 15:59:58.592000	2024-01-27 17:05:21.284000	-67.1802, 18.3633
BPR012924-822	2024-01-29 15:56:53.550000	2024-01-29 17:24:19.479000	-67.1802, 18.3633
PR012924-921	2024-01-29 17:12:10.059000	2024-01-29 18:00:46.114000	-67.14883, 18.3519
PR012924-1092	2024-01-29 19:48:24.135000	2024-01-29 20:29:53.229000	-67.15608, 18.3323
PR020224-571	2024-02-02 13:23:10.837000	2024-02-02 15:01:55.973000	-67.1802, 18.3633
BPR020224-934	2024-02-02 18:25:32.114000	2024-02-02 18:55:39.999000	-67.1802, 18.3633
BPR021424-762	2024-02-14 15:52:25.590000	2024-02-14 17:20:03.950000	-67.1802, 18.3633
BPR021724-790	2024-02-17 16:25:54.221000	2024-02-17 17:03:18.862000	-67.1802, 18.3633
PR021824-634	2024-02-18 14:39:47.980000	2024-02-18 16:36:47.042000	-67.14853, 18.3524
BPR021924-590	2024-02-19 13:57:17.119000	2024-02-19 15:51:59.536000	-67.1802, 18.3633
PR021924-764	2024-02-19 16:29:36.047000	2024-02-19 17:53:38.572000	0.0, 0.0
BPR021924-800	2024-02-19 16:47:38.093000	2024-02-19 17:13:35.587000	-67.1802, 18.3633
PR022624-958	2024-02-26 19:03:45.789000	2024-02-26 19:20:56.059000	-67.1555, 18.4242
BPR022724-727	2024-02-27 15:46:49.248000	2024-02-27 19:21:44.604000	-67.1802, 18.3633
BPR022724-950	2024-02-27 19:51:57.445000	2024-02-27 20:28:29.837000	-67.1802, 18.3633
BPR022924-1191	2024-02-29	2024-02-29	-67.1802, 18.3633

Case Number	Discovery Date	Containment Date	Local Incident Id
	20:30:34.449000	21:10:27.429000	
PR030324-80	2024-03-03 03:47:01.333000	2024-03-03 06:03:09.924000	-67.15857, 18.3424
BPR030524-2	2024-03-05 00:02:00.048000	2024-03-05 00:41:48.824000	-67.1802, 18.3633
BPR030624-721	2024-03-06 14:21:15.065000	2024-03-06 15:27:39.877000	-67.1802, 18.3633
PR031324-468	2024-03-13 11:16:35.388000	2024-03-13 12:41:30.687000	-67.15812, 18.3366
BPR031324-863	2024-03-13 16:26:44.738000	2024-03-13 17:05:13.097000	-67.1802, 18.3633
BPR031424-637	2024-03-14 13:41:02.154000	2024-03-14 14:46:03.697000	-67.1802, 18.3633
PR032024-1142	2024-03-20 20:25:51.791000	2024-03-20 21:26:45.106000	-67.15537, 18.3399
PR032224-30	2024-03-22 00:57:56.409000	2024-03-22 02:32:25.161000	-67.19975, 18.3371
BPR032624-612	2024-03-26 12:15:48.355000	2024-03-26 12:44:01.994000	-67.1802, 18.3633
BPR032724-576	2024-03-27 13:55:03.758000	2024-03-27 15:39:19.733000	-67.1802, 18.3633
PR032724-811	2024-03-27 17:01:15.966000	2024-03-27 19:46:48.981000	-67.22249, 18.3557
PR032724-1028	2024-03-27 21:15:40.901000	2024-03-27 22:23:41.712000	-67.18825, 18.3622
BPR032824-306	2024-03-28 10:18:22.856000	2024-03-28 11:21:55.412000	-67.1802, 18.3633
PR032924-384	2024-03-29 11:09:53.288000	2024-03-29 12:36:30.890000	-67.15145, 18.3925
BPR033024-112	2024-03-30 05:37:18.534000	2024-03-30 06:30:42.828000	-67.1802, 18.3633
PR033024-672	2024-03-30 16:07:24.766000	2024-03-30 17:23:35.962000	-67.1855, 18.3782
BPR040424-581	2024-04-04 13:40:57.037000	2024-04-04 14:12:24.066000	-67.1802, 18.3633
BPR040524-641	2024-04-05 14:06:50.079000	2024-04-05 14:49:32.825000	-67.1802, 18.3633
BPR040624-715	2024-04-06 15:21:35.446000	2024-04-06 15:39:51.291000	-67.1802, 18.3633
PR040824-348	2024-04-08 09:51:16.252000	2024-04-08 12:18:15.977000	-67.19986, 18.3371

Case Number	Discovery Date	Containment Date	Local Incident Id
PR040924-1089	2024-04-09 22:55:34.357000	2024-04-09 23:32:39.476000	-67.17748, 18.3789
BPR041024-464	2024-04-10 11:04:30.992000	2024-04-10 12:10:44.864000	-67.1802, 18.3633
PR041024-512	2024-04-10 11:32:02.250000	2024-04-10 12:11:32.688000	-67.17829, 18.3785
BPR041024-905	2024-04-10 17:04:08.450000	2024-04-10 17:54:36.704000	-67.1802, 18.3633
BPR041024-1043	2024-04-10 19:47:53.159000	2024-04-10 20:05:35.158000	-67.1802, 18.3633
BPR042024-1048	2024-04-20 21:50:29.811000	2024-04-20 23:00:40.911000	-67.1802, 18.3633
PR060624-481	2024-06-06 11:45:06.073000	2024-06-06 12:50:51.964000	-67.19625, 18.3795
PR121224-1004	2024-12-12 18:30:26.519000	2024-12-12 19:46:02.846000	-67.15628, 18.3727
PR012024-1038	2024-01-20 18:59:49.897000	2024-01-20 20:38:45.327000	-67.14837, 18.3509
PR033024-899	2024-03-30 19:18:07.695000	2024-03-30 19:25:09.244000	-67.16192, 18.3602
PR033024-965	2024-03-30 20:02:03.846000	2024-03-30 20:12:39.313000	-67.16088, 18.3478
BPR040424-652	2024-04-04 14:44:50.878000	2024-04-04 15:31:33.399000	-67.1802, 18.3633

4.14.1.4 Future Event Probability (B1-e)

Future wildfire probability in Aguada is expected to remain generally low to moderate; however, changing climatic conditions may increase the likelihood of wildfire occurrence over time. Although Figure 25 indicates that Aguada is not located within one of Puerto Rico's primary wildfire hotspots, the presence of vegetated areas and seasonal dry conditions continues to create opportunities for wildfire ignition and spread.

Increasing temperatures, more frequent droughts, and the spread of invasive species are making forests more susceptible to wildfires. This shift is already evident in Puerto Rico, where fires are becoming more frequent and occurring in areas with no prior history of such events (Robbins, Eckelmann, & Quiñones, 2009). These conditions can

increase wildfire susceptibility, particularly during periods of below-normal precipitation. In addition, continued human activity in and around vegetated areas may increase ignition potential, as human-caused fires remain the primary source of wildfire occurrence in Puerto Rico.

The wildfire incidents reported in Aguada during 2024 demonstrate that vegetation fires continue to occur within the municipality. While most recorded events were contained rapidly and did not result in large-scale impacts, their frequency suggests that wildfire risk will remain an ongoing concern. Continued public awareness efforts, vegetation management practices, and effective emergency response capabilities will be important to reduce future wildfire impacts and maintain community resilience.

4.14.2 Risk Analysis (B2-a, B2-b)

4.14.2.1 *Estimated Losses*

Wildfires can result from both natural conditions, such as the presence of flammable vegetation, and human activities, including the intentional use of fire. These factors strongly influence the potential scale and intensity of wildfire events. The level of potential loss increases with higher population concentrations, greater numbers of structures, and sensitive ecosystems located within the affected area. Climatic conditions, combined with patterns of human activity, largely determine the extent and severity of wildfire impacts.

At present, there is insufficient information to quantify monetary losses related to building damage from this hazard. Additionally, at the time of this Plan update, no official damage estimates were available for the municipality. To address this gap, the municipality will take a proactive approach by incorporating updated damage information in Plan revisions as data become available.

4.14.2.2 *Lifelines and Critical Infrastructure*

Wildfires pose a significant threat to critical infrastructure, creating cascading impacts across power systems, communications, water supply, transportation, and the built environment. The electric grid is particularly vulnerable. Research from Sandia National Laboratories (Sandia National Laboratories, n.d.) and other institutions shows that wildfire can both damage grid components and be ignited by them, as seen in the 2018 Camp Fire, which caused \$9.3 billion in damages. To address this, the U.S.

Department of Energy has invested \$3.46 billion through its Grid Resilience and Innovation Partnerships program (DOE, 2023), funding projects that include undergrounding power lines, installing fire-resistant poles, and deploying advanced sensors.

Communications infrastructure faces similar risks. A study by the University of Wisconsin – Madison faculty found that while cell towers often survive fires physically, power outages lead to widespread service disruptions (Anderson, Barford, & Barford, 2020). Water systems and watersheds are also heavily impacted. Post-fire conditions—such as vegetation loss and soil hydrophobicity—can trigger flooding and debris flows, introducing sediment, nutrients, and metals into water supplies.

Transportation networks suffer both direct and indirect damage. Roads, bridges, and drainage systems are often compromised by post-fire floods and debris flows. Buildings and other structures in the wildland–urban interface are increasingly at risk due to climate change and urban expansion.

In summary, wildfire creates complex, interconnected risks for critical infrastructure, requiring a combination of engineering solutions, advanced modeling, policy reforms, and community engagement. Official and academic sources consistently call for proactive measures—such as infrastructure hardening, improved land management, and resilience planning—to reduce exposure and enhance recovery.

Wildfire occurs regularly during periods of drought, primarily in the southern region of Puerto Rico. These events have significant social and economic impacts, mainly due to structural and property damage or loss caused by the fires. If the affected area served as an employment or industrial hub, many individuals could face unemployment. Additionally, insurance premiums tend to rise because of increased demand for coverage to mitigate economic losses associated with wildfire hazards. Collectively, these factors negatively affect the region's economy, wildlife, vegetation, and contribute to broader social decline.

Wildfires in Aguada can disrupt economic activity by affecting residential areas, local businesses, public facilities, and areas used for agriculture and recreation. Fires occurring near developed areas may require road closures, emergency response activities, and temporary interruptions to commercial operations, resulting in economic losses and additional recovery costs. Agricultural lands and grazing areas may also experience losses associated with damaged vegetation and reduced productivity. In addition, wildfire events can diminish the recreational and aesthetic

value of natural areas, potentially affecting outdoor activities and local tourism. Collectively, these impacts may create short-term economic disruptions while placing additional demands on municipal resources and emergency services.

4.14.2.3 Social Vulnerability

Social vulnerability plays a critical role in shaping how communities experience and recover from wildfire events. Research consistently shows that populations with higher levels of poverty, older adults, individuals with disabilities, limited English proficiency, and households without reliable transportation face greater challenges preparing for, evacuating from, and recovering after wildfires. The CDC/ATSDR Social Vulnerability Index (SVI) identifies these demographic and socioeconomic conditions as key factors that increase susceptibility to disaster impacts, including wildfires, by constraining a community's adaptive and coping capacity before, during, and after an event. National-scale studies further demonstrate that U.S. communities experiencing wildfire occurrence or exposure tend to have systematically higher levels of social vulnerability, including higher unemployment, lower educational attainment, and greater concentrations of medically or socially dependent populations (Schumann, III, et al., 2024).

Wildfires also exacerbate existing inequalities through indirect impacts such as prolonged displacement, loss of livelihoods, and health effects from smoke exposure. Peer-reviewed studies show that socially vulnerable populations experience disproportionate health burdens from wildfire smoke, including higher rates of respiratory and cardiovascular illness and increased mortality risk, due to pre-existing health conditions and limited access to medical care. FEMA and the U.S. Fire Administration emphasize that older adults, low-income households, people living in mobile homes, and individuals without access to private vehicles face heightened risk of injury or death during wildfire evacuations, underscoring the importance of incorporating social vulnerability into wildfire mitigation, evacuation planning, and recovery strategies. (Dennin, Nock, Muller, Akindele, & Adams, 2025) (Dennin, Nock, Muller, Akindele, & Adams, 2025)

4.14.2.4 Natural and Cultural Resources

The severity, scale, and consequences of wildfire can be grouped into the following categories:

- Impact on Landscape - The most visible effect after a wildfire is the loss of scenic quality caused by the destruction of vegetation cover and its regression to earlier ecological stages.
- Impact on Wildlife - Wildfires have both immediate and long-term effects on fauna. In the short term, fires can cause direct mortality, particularly among invertebrates, small vertebrates, and young animals with limited mobility, as well as larger herbivores and carnivores that may be trapped by flames or barriers such as fencing. In the longer term, habitat loss, reduction of forage, and ecosystem disruption can force wildlife migration and threaten vulnerable or endangered species.
- Impact on Soil - Wildfires significantly alter soil structure and increase its susceptibility to erosion. The combustion of organic matter destabilizes soil aggregates, causing progressive disintegration. As a result, solid particles are then removed by rain or wind erosion. Fire often creates hydrophobic (water-repellent) layers to the deposition of organic compounds and changes in mineral composition, which reduce water infiltration and further accelerate surface runoff and erosion. Significant losses of soil and organic matter reduce nutrient levels, lowering fertility. In addition, heat also kills many organisms, reducing biological activity and disrupting biogeochemical cycles. However, not all effects are negative. Naturally occurring fires (now increasingly rare) can benefit forest health by mobilizing nutrients and controlling pests. Low-intensity fires help retain carbon in the soil, preventing its release as carbon dioxide.
- Alteration of the Water Cycle - Wildfire-induced soil degradation can significantly disrupt the hydrological cycle. Reduced infiltration lowers groundwater reserves that feed aquifers essential for agriculture and urban use. At the same time, increased surface runoff accelerates soil erosion, transports sediment into water bodies, and heightens the risk of flash flooding following intense rainfall events.
- Increase in Carbon Emissions - The combustion of biomass during wildfires releases substantial quantities of carbon dioxide (CO₂), methane (CH₄), and suspended particles. These emissions cause significant environmental damage and negatively affect people with respiratory illness (Asthma, COPD, etc.).

Wildfires can lead to numerous environmental consequences, including the destruction of vegetation cover, the death or displacement of wildlife, the loss of fertile soil, and an increase in erosion events. They can also cause significant loss of life and property, resulting in substantial economic costs associated with firefighting and recovery efforts.

As for cultural resources, wildfires pose a serious threat to cultural resources, including historic buildings, and archaeological sites. Intense heat and flames can destroy irreplaceable structures, artifacts, and archives, erasing centuries of heritage in a matter of hours. In addition, smoke, soot, and water used during firefighting operations can further damage delicate materials. Post-fire effects such as erosion and flooding after fires may expose or wash away archaeological remains.

Beyond physical damage, the loss of cultural landmarks disrupts can community identity and traditions, while also affecting tourism and local economies. Protecting these resources requires proactive planning, fire-resistant measures, and collaboration between emergency agencies and cultural preservation experts.

4.14.2.5 Future Conditions (E1-a)

Puerto Rico already experiences a high annual probability of wildfire-supporting conditions. According to the World Bank-supported ThinkHazard! platform, Puerto Rico's wildfire hazard is classified as High, meaning there is a greater than 50% probability in any given year of weather conditions capable of supporting a significant wildfire that could cause impacts to life or property. This assessment incorporates historical fire occurrence, climate variables, vegetation type, and drought conditions and is widely used in infrastructure and hazard mitigation planning worldwide (World Bank, n.d.).

Taken together, the best available scientific evidence indicates that Puerto Rico currently faces a probability exceeding 50% annually of wildfire-supportive weather conditions, with future probability and severity expected to increase due to rising temperatures, expanded drylands, and longer seasonal droughts. While precise ignition probability percentages cannot be reliably projected at the municipal scale, confidence is high that wildfire occurrence, fire weather days, and burned area will increase by mid-century, particularly in southern, western, and interior regions of the island (World Bank, n.d.).

4.15 Long Term Coastal Dynamics

4.15.1 Description

Long-term coastal dynamics refer to the gradual, persistent processes that shape coastlines over extended periods of time, including shoreline movement, sediment transport, erosion, accretion, and changes in coastal water levels, which together influence coastal form, stability, and hazard exposure (USGS, 2018) (Mentaschi, Voudoukas, Pekel, Voukouvalas, & Feyen, 2018). These dynamics differ from short-term storm impacts in that they reflect persistent, incremental change rather than episodic disturbance. For Local Hazard Mitigation Plans, understanding long-term coastal dynamics is critical because such changes influence shoreline position, coastal stability, and long-term exposure to coastal hazards (USGS, 2018).

Long-term coastal dynamics are primarily driven by the interaction of coastal erosion, coastal accretion, and changes in the mean (base) sea level, all of which influence sediment distribution, natural protective features, and flood exposure along coastal areas (Bird, 2008; Davidson-Arnott, 2010).

Coastal Erosion

Coastal erosion is the long-term landward movement of the shoreline resulting from a net loss of sediment from beaches, dunes, bluffs, or nearshore environments. While erosion may occur rapidly during storm events, long-term erosion reflects sustained sediment imbalance operating over decades (Komar, 1998).

From a hazard mitigation perspective, chronic coastal erosion is important because it gradually reduces beach width and elevation, weakens dune systems, and exposes inland areas to increased wave action and flooding. Long-term erosion is commonly measured as average annual shoreline retreat, integrating multiple historical shoreline positions and providing an indicator of sustained vulnerability rather than

isolated event-driven damage (Allan et al., 2003; USGS, 2018).

Coastal Accretion

Coastal accretion refers to the long-term accumulation of sediment that results in shoreline advancement or increases in beach width and elevation. Accretion can enhance coastal resilience by reinforcing natural protective features; however, it is often spatially variable and dependent on sediment availability and transport pathways (Davidson-Arnott, 2010).

In many coastal systems, accretion in one location corresponds to erosion elsewhere, reflecting sediment redistribution rather than net sediment gain. As a result, accretion may be temporary and insufficient to offset long-term erosional trends at a regional scale (Bird, 2008; Mentaschi et al., 2018).

Variations in Mean (Base) Sea Level

Mean sea level, often referenced using tidal datums such as mean sea level (MSL) or mean higher high water (MHHW), serves as a controlling baseline for coastal processes. Long-term changes in mean sea level influence the elevation at which waves interact with the shoreline, the frequency of tidal inundation, and the position of the coastal profile (USGS, 2018).

Gradual changes in mean sea level contribute to long-term coastal dynamics by promoting landward adjustment of beaches and dunes, increasing inundation during routine tides, and enhancing erosion during moderate storm conditions. These impacts occur incrementally and contribute to persistent shoreline retreat over time (Bird, 2008; Mentaschi et al., 2018).

Long-term coastal dynamics emerge from the interaction of erosion, accretion, and mean sea-level position rather than from any single process acting independently. Coastal systems tend to adjust toward equilibrium conditions, which may involve shoreline migration, redistribution of sediment, and progressive loss of natural buffering capacity (Davidson-Arnott, 2010).

As a result, localized accretion may slow erosion but may not reverse long-term shoreline retreat where underlying sediment deficits or water-level changes persist. These interactions explain why many coastlines experience sustained landward movement despite episodic periods of beach recovery (Komar, 1998; Allan et al., 2003).

For Local Hazard Mitigation Plans, long-term coastal dynamics are a key consideration because they contribute to the gradual expansion of coastal hazard exposure beyond areas affected by single storm events. Persistent erosion, shifting shorelines, and changing base water levels can increase the vulnerability of infrastructure, reduce the effectiveness of fixed shoreline protection measures, and influence long-term land-use suitability (USGS, 2018).

Incorporating long-term coastal dynamics into hazard mitigation planning supports proactive decision-making related to land use, infrastructure siting, and mitigation strategy development by addressing the underlying physical processes shaping coastal risk.

Long-term coastal dynamics, including ongoing erosion, accretion, and changes in mean sea level, contribute to gradual shoreline adjustment and increased exposure to coastal hazards over time. These processes represent a persistent source of coastal risk that should be considered in land-use planning, infrastructure investment, and hazard mitigation strategies (Bird, 2008; USGS, 2018).

4.15.1.1 Affected Area

The municipality has 10.57 km of coastline, of which 9.86 km (93%) consists of beaches. The coastline contains various hard structures along approximately 0.70 km. The identified types of hard structures include boat ramps and ripraps (rock revetments). It is evident that most of the hard structures in the area contribute to erosion on one side of the structure, suggesting that these structures are interrupting the natural longshore transport of sediments.

Following Hurricane María, erosion was observed along 44% of the beach coastline. As of September 2017, the sectors most affected by erosion within the municipality were located in beach sections containing hard structures, including the Pico de Piedra area, the area north of Aguada Municipal Beach, and La Playa Sector in Barrio Espinar. However, ten months after the hurricane, recovery was identified along several shoreline segments, with 81% accretion observed along the beach coastline.

By July 2018, landward beach migration was identified along 2.98 km of shoreline, while shoreline (waterline) migration was identified along 1.72 km within the municipality, specifically from the Culebrinas River to Playa Espinar, Playa Cañones, Aguada Municipal Beach, Playa Guaniquilla, and Aguada Beach.

Under HMGP FEMA-4339-DR-PR Subgrantee Number 4339-0007P, a comprehensive post-event coastal assessment was conducted to evaluate the geomorphic condition of Puerto Rico's beaches following Hurricane María (September 2017) and their subsequent recovery. This study was conducted by the University of Puerto Rico, Río Piedras' Coastal Research and Planning Institute of Puerto Rico (COREPI-PR).

The assessment analyzed beach conditions immediately after the hurricane and approximately ten months later (July 2018), covering a representative group of coastal municipalities across the north, west, east, and south coasts including Aguada, Aguadilla, Añasco, Arecibo, Arroyo, Barceloneta, Humacao, Loíza, Rincón, and San Juan (COREPI-PR, 2020).

Figure 26 (only available in Spanish) presents the results of the COREPI-PR coastal assessment for the Municipality of Aguada. The figure illustrates the distribution of coastline types and summarizes post-Hurricane María coastal conditions, including shoreline and beach migration, the extent of hard coastal structures, and the proportion of beach segments exhibiting erosion and accretion during the September 2017 and July 2018 assessments (COREPI-PR, 2020).

Figure 26. State of the Beach Study



Aguada

Estado de la costa



Mapa preparado por: COREPI-PR
Digitalizado por: David Peña-De Jesús
Fuente de Imagen: ESRI
*Inventario de Playas 2018, M. Barreto & et al. (en proceso de publicación)
**Incluye estructuras duras múltiples que no necesariamente son de mitigación

0 0.5 1 2 Kilómetros

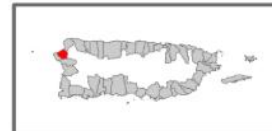
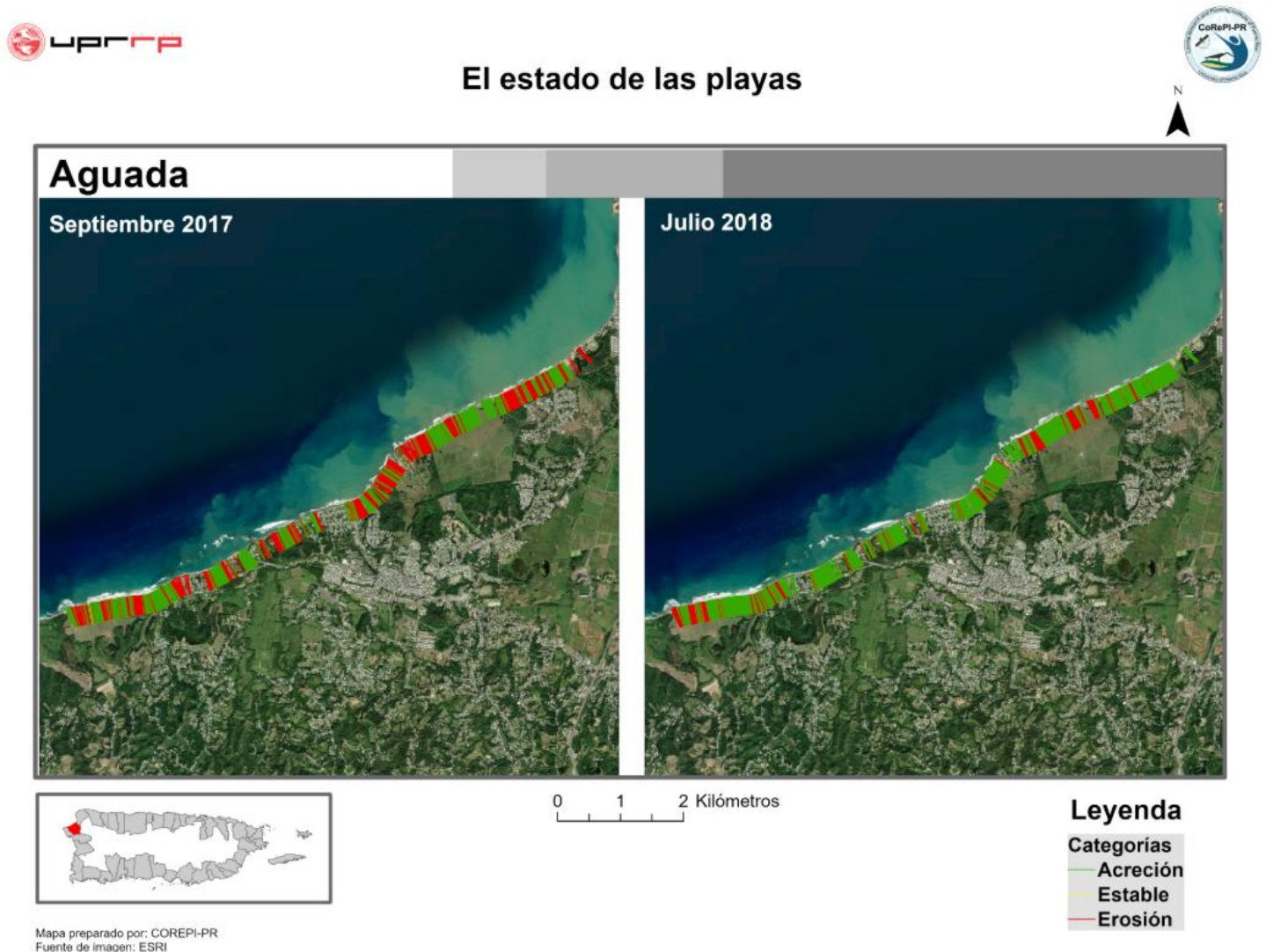


Figure 27 (only available in Spanish) compares beach conditions in September 2017, immediately after Hurricane María, and July 2018, approximately ten months later. Beach segments are classified as erosion, stability, or accretion. The comparison shows a reduction in erosive conditions and an increase in accretional segments between the two assessment periods, indicating shoreline recovery along several sectors of the municipality's coastline (COREPI-PR, 2020).

Figure 27. State of the Beach (Erosion vs. Accretion)

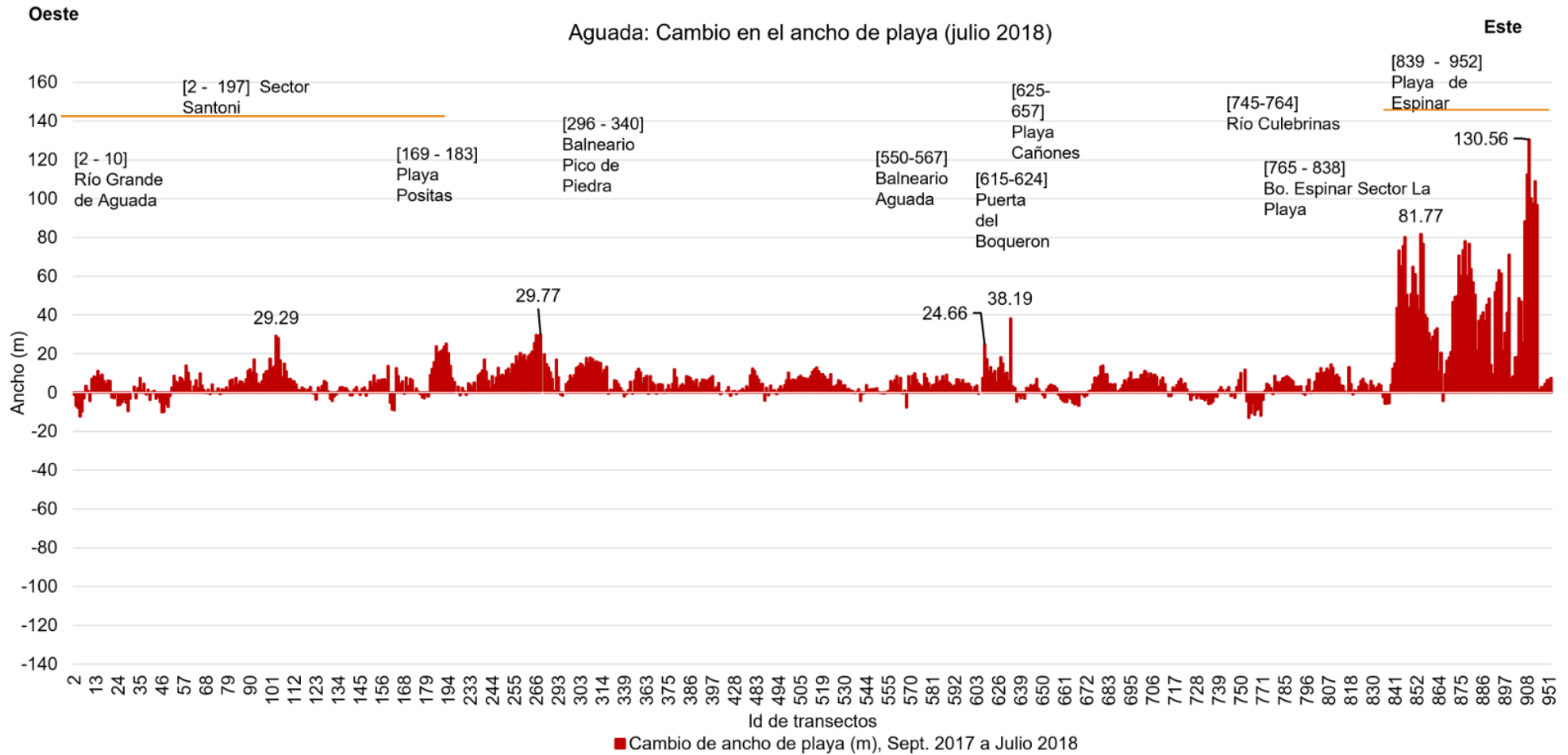


Finally Figure 28 illustrates variations in beach width along transects distributed across the municipality's coastline. Positive values indicate beach widening (accretion), while

negative values indicate beach narrowing (erosion). Most transects show positive changes in beach width between September 2017 and July 2018, with the largest increase observed in the Playa Espinar sector. Localized areas of erosion remain present along portions of the coastline, reflecting the spatial variability of post-Hurricane María beach recovery processes (COREPI-PR, 2020).

The analysis of beach width changes between September 2017 and July 2018 indicates an overall recovery trend along Aguada's coastline. Although localized areas experienced reductions in beach width, most transects exhibited positive changes, with the most significant increases observed in the eastern portion of the municipality, particularly near Playa Espinar. These findings suggest that sediment deposition and beach rebuilding processes were active during the post-Hurricane María recovery period, although spatial variability in shoreline response remains evident along the coast.

Figure 28. Change in Width of Beach (July 2018)



4.15.1.2 Risk Magnitude

Coastal Erosion

Erosion is the process by which major storms, flooding, strong wave action, rising sea levels, and human activities wear away beaches and cliffs along coastlines (FEMA, 1997). Beaches are affected by storms and other natural events that cause coastal erosion; however, the extent and severity of the problem are not uniform, as they vary by location. Consequently, there is no single solution for mitigating erosion. Erosion processes and their impacts may be episodic or long-term. These two (2) descriptors assign an important temporal component to erosion processes and their consequences.

Episodic erosion, also known as storm-induced erosion, primarily consists of the cross-shore movement of sand and sediments resulting from high-intensity weather events and ocean storms. This type of response leads to coastal adjustment and occurs during a single storm or a sequence of storm events within a season. Changes in beach and shoreline profiles during intense storms may result in dramatic erosion of beaches and dunes, including the reduction or removal of coastal dunes, as well as the retreat and collapse of coastal cliff formations. The consequences of this type of erosion may include increased inland wave penetration and ocean flooding in areas that were previously not exposed to water inundation.

Long-term or chronic erosion, on the other hand, is associated with slower processes such as gradual shoreline change linked to:

- Increases in sea level,
- Land subsidence,
- Changes in sediment supply due to watershed modifications,
- Impacts on coral reefs resulting from rising water temperatures and ocean acidification,
- Coastal structures and development, and
- Decadal adjustments in rainfall, wind, and climate associated with global warming.

Erosion may also be caused by anthropogenic forces (Romeu-Cotchett, 2012), including:

- Removal of coastal sediments, resulting in area erosion and the loss of dunes and beaches;
- Construction of developments, roadways, or agricultural activities, which increase sediment deposition and contamination in coastal waters, causing adverse effects on coral reefs. It should be noted that reefs function as natural barriers that protect beaches from wave impacts and, consequently, from erosion;
- Dam systems constructed to reduce the normal flow of sand delivered to the ocean by rivers; and
- The construction of buildings, infrastructure, and other coastal developments in close proximity to beaches can alter natural shoreline processes and reduce the available space for beach and dune migration. As a result, wave energy becomes concentrated along the shoreline, increasing sediment loss and accelerating erosion. Over time, these conditions may contribute to beach narrowing, shoreline retreat, the degradation of protective dune systems, and increased exposure of coastal communities and infrastructure to coastal hazards.

Costal Accretion

Coastal accretion is a fundamental component of long-term coastal dynamics and represents the process by which sediment is deposited along the shoreline, resulting in the widening, elevation, or seaward movement of beaches, dunes, and other coastal landforms. Accretion occurs when sediment inputs exceed sediment losses over time and plays a critical role in shaping shoreline configuration and influencing coastal hazard exposure (USGS, 2018).

For Mitigation planning coastal accretion is significant because it affects the capacity of beaches and dunes to function as natural protective features that reduce wave energy, coastal flooding, and erosion impacts. However, accretion is neither uniform nor permanent and must be evaluated in terms of its duration, spatial extent, and relationship to broader coastal processes (Bird, 2008).

Episodic coastal accretion refers to short-term sediment deposition that occurs following discrete events or over limited periods, such as between storm seasons. This form of accretion is typically associated with the return of sediment from offshore bars or adjacent shoreline segments to the beach through cross-shore or alongshore transport processes (Davidson-Arnott, 2010).

Episodic accretion may result in temporary increases in:

- Beach width,
- Beach elevation, and
- Dune volume following storm-related erosion.

These changes may occur rapidly, sometimes within weeks or months; however, episodic accretion represents temporary profile adjustment rather than sustained shoreline stabilization. Subsequent storms or shifts in hydrodynamic conditions may quickly redistribute or remove accreted sediments (Komar, 1998).

From a hazard mitigation perspective, episodic accretion may reduce short-term exposure to wave action or tidal inundation but should not be assumed to provide long-term protection unless supported by evidence of persistent sediment supply.

Long-term coastal accretion occurs when sediment deposition persists over years to decades, resulting in stable or progressively advancing shorelines. This form of accretion reflects a positive sediment budget within the coastal system, often supported by consistent sediment delivery and favorable transport conditions (USGS, 2018).

Long-term accretion is commonly associated with:

- Sustained sediment input from rivers or coastal ecosystems,
- Alongshore sediment transport that concentrates material in specific shoreline segments,
- Nearshore bathymetry that favors sediment retention, and
- Relatively stable mean sea-level conditions relative to land elevation (Bird, 2008).

While long-term accretion can enhance coastal resilience by reinforcing beaches and dunes, it is often spatially limited and may occur concurrently with erosion in adjacent areas. In many cases, accretion reflects sediment redistribution rather than net sediment gain across a regional coastline (Mentaschi et al., 2018).

Human activities can influence coastal accretion both directly and indirectly. In some cases, engineered interventions such as beach nourishment or coastal structures may promote localized sediment accumulation. In other cases, development and infrastructure interfere with natural sediment pathways, limiting accretion potential elsewhere (Komar, 1998).

Anthropogenic factors affecting accretion include:

- Beach nourishment and sediment placement projects,
- Coastal structures that trap sediment locally,
- Alterations to river systems that modify sediment delivery, and
- Shoreline development that restricts natural shoreline adjustment (NOAA, 2020).

While engineered accretion may provide short- to medium-term protective benefits, it typically requires long-term maintenance and should be evaluated within the context of sustained coastal dynamics.

Change in Base Sea Level Mean

Changes in the mean (base) sea level, commonly referenced using tidal datums such as mean sea level (MSL) or mean higher high water (MHHW), represent an important component of long-term coastal dynamics and influence the frequency and extent of coastal inundation. Mean sea level serves as a baseline against which shoreline position, wave interaction, and tidal flooding are measured, and gradual shifts in this baseline affect how coastal systems respond over time (NOAA, 2026). Sustained increases in mean sea level relative to the land surface allow wave energy to act on higher portions of the coastal profile, increasing the frequency of tidal flooding and accelerating shoreline adjustment processes. These incremental changes can lead to landward migration of beaches and dunes, greater exposure of low-lying areas to coastal flooding, and reduced effectiveness of natural and engineered protective features, even in the absence of major storm events. From a hazard mitigation planning perspective, changes in mean sea level contribute to long-term increases in coastal hazard exposure and should be considered when evaluating future risk, land-use suitability, and infrastructure resilience along the coast (USGS, 2018) (NOAA, 2026).

Sea level fluctuates over both short- and long-term timeframes because of multiple interacting factors. Short-term variations typically occur on daily to event-based timescales and are influenced by processes such as waves, tides, and discrete flooding events, including those associated with seasonal snowmelt, hurricanes, or other coastal storms. In contrast, long-term sea-level variations occur over extended periods ranging from months to multiple years and may manifest as recurring cycles, gradual trends, or episodic departures from typical conditions. These longer-term

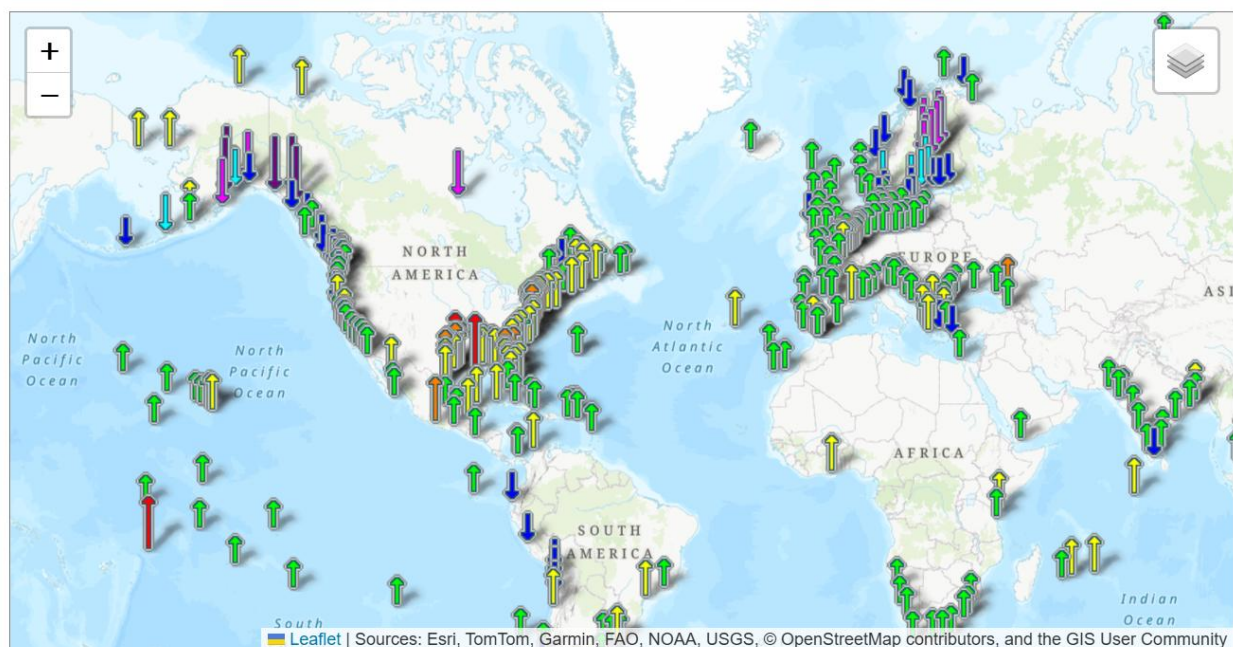
changes are influenced by a combination of factors, including seasonal atmospheric patterns, variations in the Earth's declination, changes in coastal and ocean circulation, human activities such as dredging, vertical land motion, and large-scale climate–ocean oscillations such as the El Niño–Southern Oscillation.

When evaluating long-term sea-level trends, a minimum observational record of 30 years is commonly used to capture these underlying variations and minimize uncertainty associated with shorter-term fluctuations in monthly mean sea level. Accounting for predictable and repeatable processes—such as tidal cycles, seasonal variability, and interannual oscillations—allows for a more accurate representation of long-term sea-level behavior (NOAA, 2026).

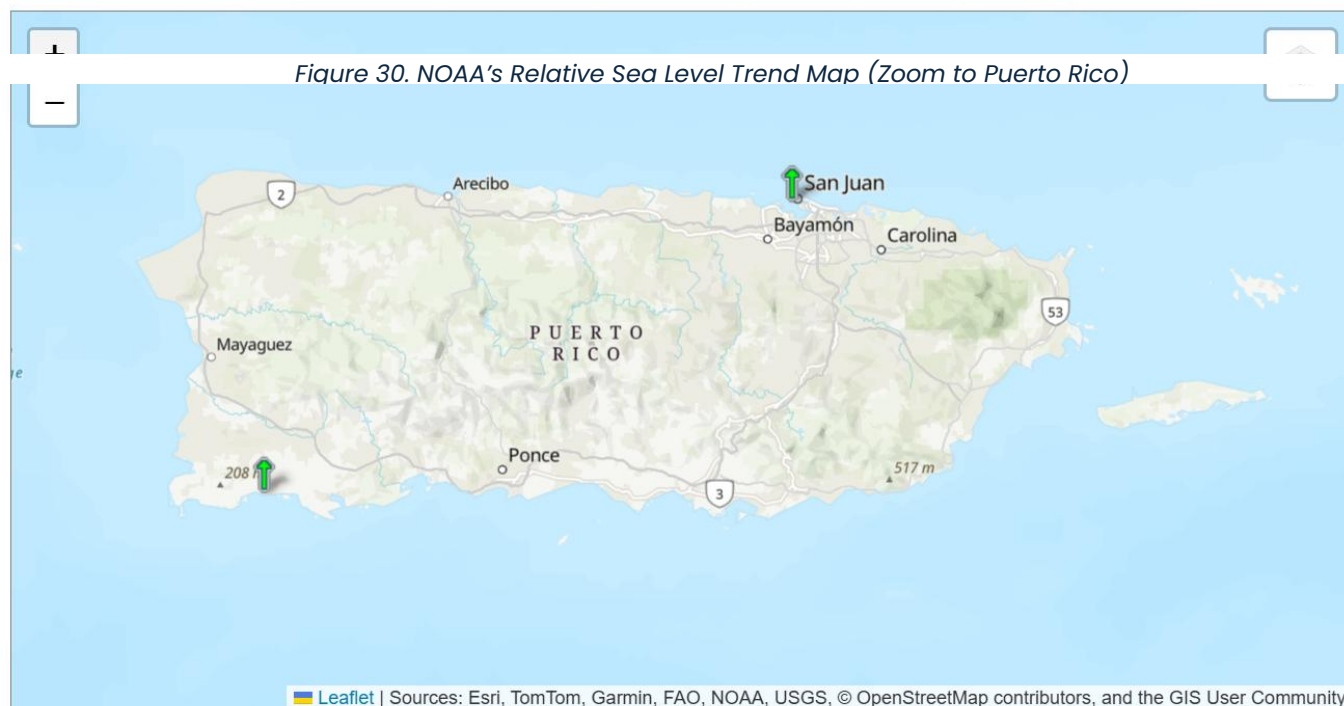
NOAA's Relative Sea Level Trends website provides the up-to-date trends for sea levels at a global scale. The global sea-level trend has been measured using satellite altimetry since 1992, and the most recent global estimates, along with maps showing regional variations, are available from NOAA's Laboratory for Satellite Altimetry. The screen shot below shows the map provided by NOAA as of 4/29/2026 (NOAA, 2026).

As figure 29 show, although there are various places where the sea level has decreased (specially to the south of Alaska, the west of British Columbia, Hudson Bay, the Nordic countries and among some parts of the South American western coast (Ecuador, Peru and northern Chile) the general trend is for an increasing sea level in

Figure 29. NOAA's Relative Sea Level Trend Map



varying degrees. In the case of Puerto Rico, it has been observed an increase in base



sea levels according to Figure 30.

As illustrated in Figure 30, NOAA tide gauge records for Puerto Rico show a measurable and sustained increase in relative sea level over the past several decades. These long-term observations provide important evidence of changing coastal conditions and support the assessment of future coastal erosion, flooding, and shoreline retreat hazards. The observed trends for the Magueyes Island and San Juan gauge stations are presented in Table 49.

Table 49. Puerto Rico Sea Level Observations

Gauge Name	Trend	Period	Commentary
Magueyes Island, PR 9759110	+ 2.06/year	1955 - 2025	The relative sea level trend is 2.06 mm/year with a 95% confidence interval of +/- 0.27 mm/year based on monthly mean sea level data from 1955 to 2025 which is equivalent to a change of 0.68 feet in 100 years.

Gauge Name	Trend	Period	Commentary
San Juan, PR 9755371	+2.16/year	1962 - 2025	The relative sea level trend is 2.16 mm/year with a 95% confidence interval of ± 0.32 mm/year based on monthly mean sea level data from 1962 to 2025 which is equivalent to a change of 0.71 feet in 100 years.

Figure 31 presents the long-term relative sea level trend recorded at the NOAA tide gauge station at Magueyes Island, Puerto Rico. The record shows an average relative sea level rise of approximately 2.06 mm per year, indicating a persistent increase in sea level along Puerto Rico's southwestern coast over the period of observation.

Figure 31. Relative Sea Level Trend 9759110 Magueyes Island, PR

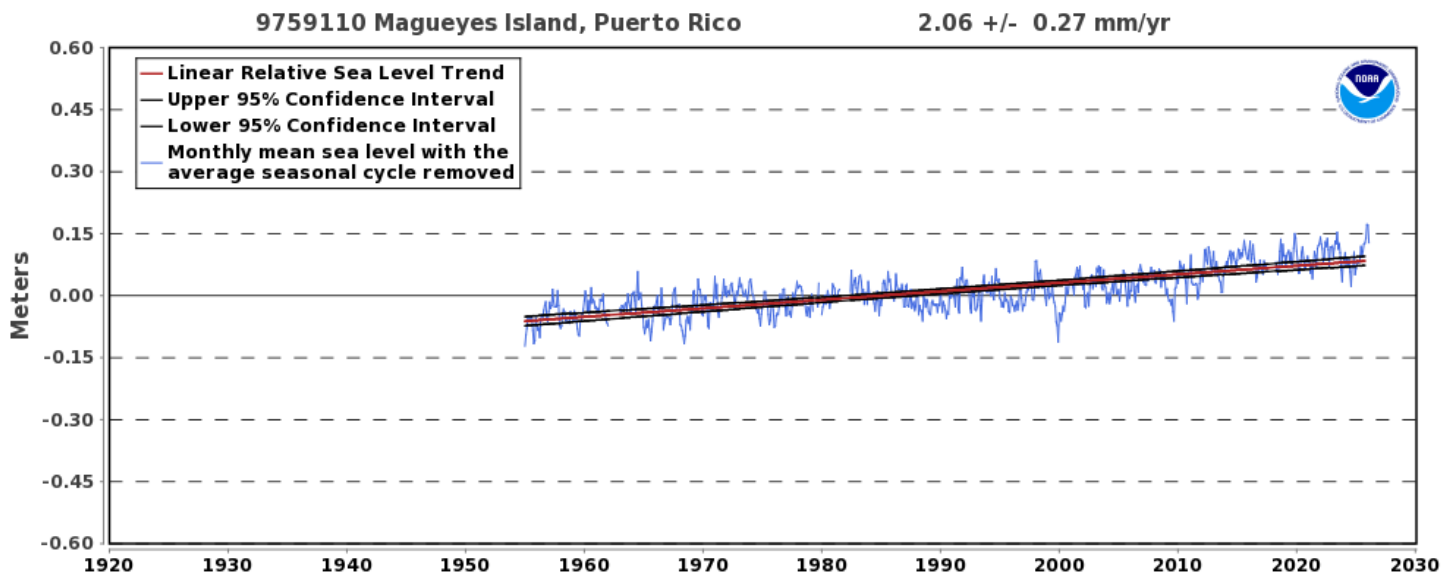
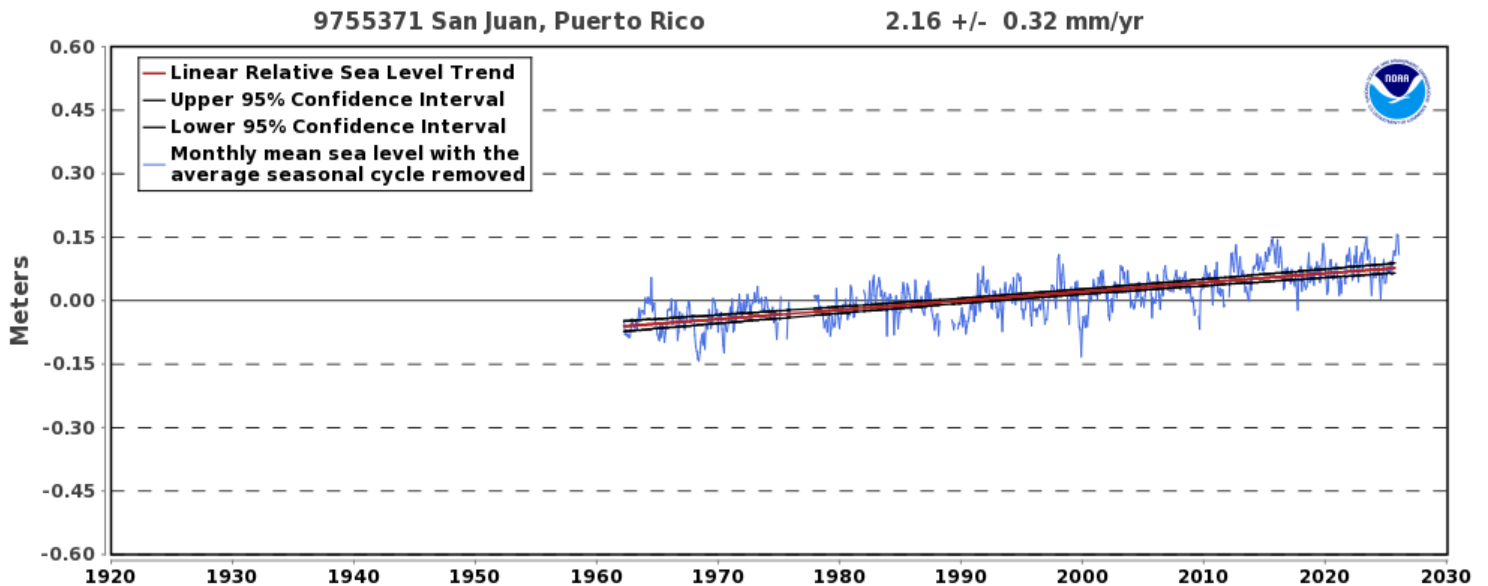


Figure 32 presents the long-term relative sea level trend recorded at the NOAA tide gauge station in San Juan, Puerto Rico. The record indicates an average sea level rise of approximately 2.16 mm per year over the period of record, demonstrating a sustained increase in relative sea level along Puerto Rico's northern coast.

Figure 32. Relative Sea Level Trend 9755371 San Juan, PR



The tide gauge records from both San Juan and Magueyes Island show a consistent long-term rise in relative sea level across Puerto Rico. Although the rates vary slightly between locations, the observed trends indicate that sea-level rise is an ongoing process affecting the Island's coastlines. Over time, these conditions may contribute to increased coastal erosion, shoreline retreat, more frequent coastal flooding, and greater vulnerability of coastal communities and infrastructure.

4.15.1.3 Past Events

Section 4.15.1.1 above details the changes in beach erosion or accretion for the beaches in Aguada in the aftermath of Hurricane Maria as detailed in the COREPI-PR study.

This study brought forth the following key findings (COREPI-PR, 2020):

- **Widespread Coastal Erosion:** Significant erosion occurred along multiple beach segments following Hurricane María, particularly in Arroyo, Humacao, and Barceloneta, reducing beach width and elevation and increasing exposure to storm surge and flooding. <https://storymaps.arcgis.com/stories/ac6e366a14d840e88a266d23b440ab0c>
- **Partial Natural Recovery:** Ten months after the hurricane, many beaches exhibited sediment accretion and partial recovery; however, recovery was

uneven and site-specific, with some areas remaining highly vulnerable to future events.

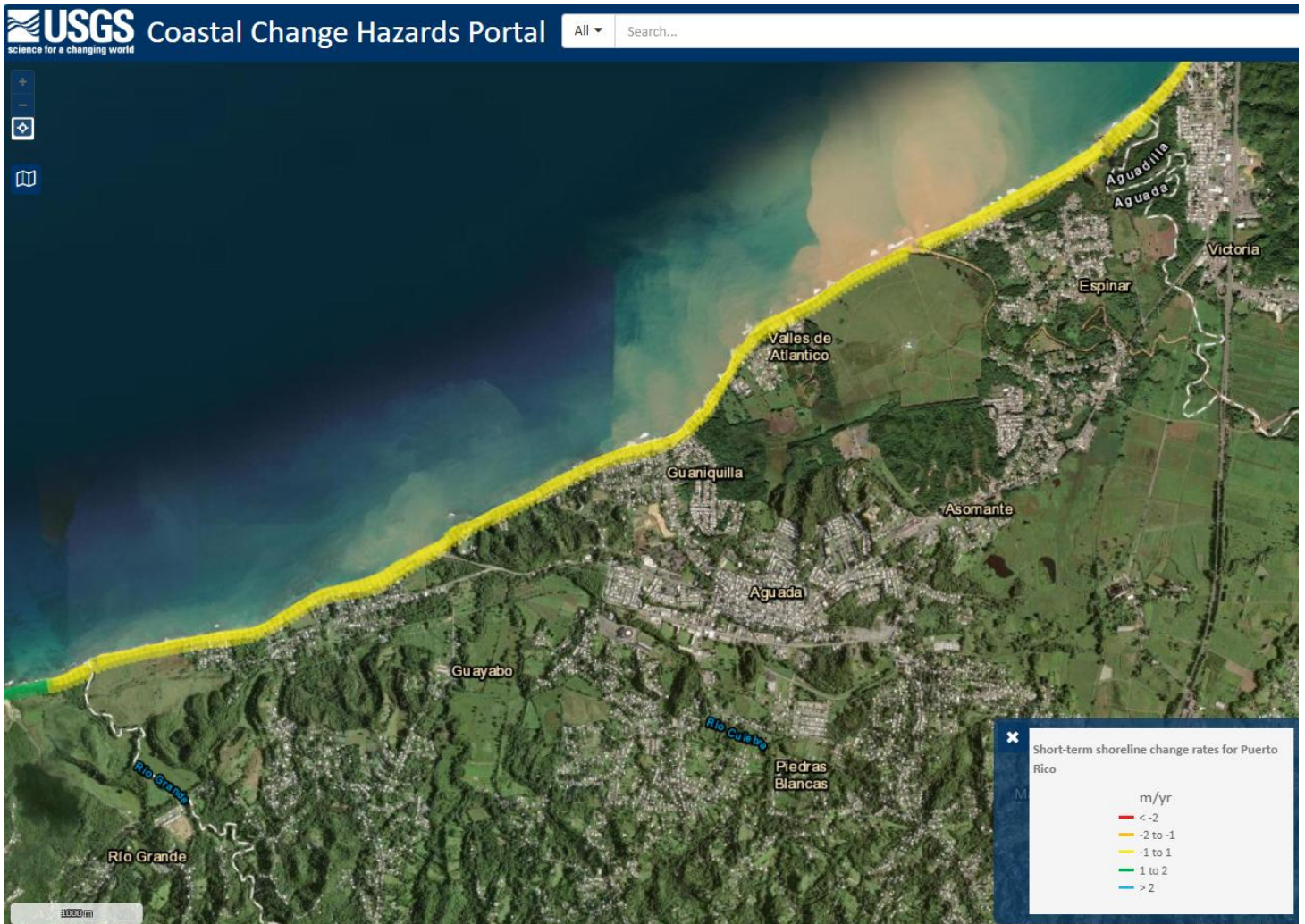
- **Beach Migration:** The study documented permanent inland migration of beaches in several municipalities, including Añasco, Humacao, Arecibo, Aguada, and Rincón. This indicates a long-term shift of the shoreline landward, increasing risk to inland infrastructure and properties.
- **Influence of Built Infrastructure:** Erosion was frequently observed adjacent to rigid shoreline structures (e.g., seawalls, rip-rap, coastal development), suggesting that hardened shorelines may exacerbate erosion processes and reduce natural beach resilience.
- **Loss of Protective Function:** In several locations, the reduction of beach width and loss of sandbars diminished the beach's capacity to function as a natural protective barrier, resulting in greater susceptibility to storm surge damage during subsequent events (e.g., 2018 extra-tropical storms).

The findings of this study are important for hazard mitigation planning since beaches are a critical natural infrastructure that provide coastal protection by dissipating wave energy, reducing flooding extent, and protecting inland development. The documented erosion, beach migration, and reduced protective capacity highlight increased vulnerability to; coastal flooding, storm surge, wave action and progressive shoreline retreat.

These findings support the integration of coastal erosion monitoring, nature-based solutions, land-use planning controls, and adaptive shoreline management strategies into local and regional hazard mitigation efforts. The assessment also provides a baseline for prioritizing mitigation projects and for validating requests for local, state, and federal mitigation funding.

Figure 33 illustrates short-term shoreline change rates along the Aguada coastline as documented by the USGS Coastal Change Hazards Portal. Most shoreline segments are classified within the range of -1 to 1 meter per year, indicating relatively stable shoreline conditions with localized areas of erosion and accretion. These results suggest that, while shoreline changes are occurring, much of the municipality's coast has experienced limited short-term positional changes relative to other highly dynamic coastal environments.

Figure 33 – Short – Term Historical Shoreline Changes



Overall, the shoreline change analysis indicates that Aguada has experienced localized shoreline variability, with most coastal segments exhibiting relatively stable short-term change rates. However, the documented inland migration of beaches and post-Hurricane María shoreline adjustments demonstrate that coastal processes continue to alter the municipal coastline. These trends highlight the importance of continued shoreline monitoring, conservation of natural coastal features, and the implementation of sustainable coastal management practices to reduce long-term erosion risks and support shoreline resilience.

4.15.1.4 Future Events Probability

The USGS has created a Coastal Change Likelihood assessment that “combines over twenty coastal data sources that describe the landscape and the hazards that act on it to determine the future likelihood of change on the coast on a decadal scale (USGS, 2026). Unfortunately, this tool is not yet available for Puerto Rico.

However given the higher probability of storms and rough seas reaching Aguada and anthropogenic changes to the coast, it is highly likely this hazard will continue to affect the municipality.

4.15.2 Risk Analysis

4.15.2.1 Estimated Losses

Currently, insufficient data are available to estimate the monetary losses resulting from long-term coastal dynamics, including shoreline retreat, beach migration, and coastal erosion.

4.15.2.2 Lifelines and Critical Infrastructure

Coastal Erosion

Coastal erosion is a long-term, progressive hazard that results in the loss of shoreline, land instability, and the degradation of natural protective features such as beaches, dunes, and wetlands. This hazard is driven by wave action, coastal storms, flooding, and long-term shoreline change processes, and it poses increasing risks to developed coastal areas and supporting infrastructure. In coastal communities, erosion directly affects the Community Lifelines that are essential to public safety, economic stability, and effective emergency response (FEMA, 2024).

- Safety and Security Lifeline is particularly vulnerable to coastal erosion. Law enforcement facilities, fire stations, emergency operations centers, and evacuation routes located near the shoreline may experience increasing exposure as erosion undermines foundations, access roads, and protective buffers. Roadway narrowing or collapse caused by shoreline retreat can reduce emergency response times and limit evacuation capacity during hazard events, placing residents and responders at greater risk (FEMA, 2021)
- The Food, Water, and Shelter Lifeline is also impacted as erosion threatens utility

infrastructure and housing stock. Water distribution lines, wastewater systems, and stormwater infrastructure may become exposed or damaged as coastal land erodes, increasing the risk of service disruptions and water quality concerns. In areas where erosion leads to the loss of residential structures, displaced households may require emergency shelter and housing assistance. Additionally, erosion affecting ports, coastal roads, and access points can disrupt food supply chains and the delivery of essential goods, particularly in geographically isolated or island communities (FEMA, 2024).

- Coastal erosion can adversely affect the Health and Medical Lifeline by limiting access to healthcare facilities and emergency medical services. Hospitals, clinics, and pharmacies located in erosion-prone areas may face increased structural risk or reduced accessibility. Transportation disruptions caused by erosion can delay emergency medical response and impede the delivery of medical supplies. Secondary public health concerns may arise when erosion damages water and wastewater infrastructure, potentially increasing exposure to contaminants or unsanitary conditions (USGS, 2025); (FEMA, 2021).
- The Energy Lifeline, including power generation, transmission, and fuel systems, is highly susceptible to erosion-related impacts. As shorelines retreat, erosion can expose underground electrical lines, pipelines, substations, and fuel storage facilities that were previously protected by coastal landforms. Damage to this infrastructure can result in power outages or fuel shortages, affecting residents, critical facilities, and emergency response operations that rely on consistent energy supply (USACE, 2013); (FEMA, 2021)
- Erosion also threatens the Communications Lifeline by damaging or destabilizing physical infrastructure such as cell towers, fiber-optic cables, and communications hubs located in coastal areas. Loss of communications systems can impair emergency notification, 911 services, and coordination among response agencies. Reduced system redundancy along eroding shorelines increases the likelihood that communications outages will occur during coastal hazard events (FEMA, 2024).
- The Transportation Lifeline experiences direct and cascading impacts from coastal erosion. Roads, bridges, ports, ferry terminals, and coastal airports may be undermined or rendered inoperable as erosion progresses. Transportation disruptions limit evacuation routes, restrict access for emergency responders, slow the delivery of supplies, and delay recovery operations. These impacts can

have significant economic consequences and prolong community recovery following disaster events (USGS, 2023).

- Finally, coastal erosion may affect the Hazardous Materials Lifeline by exposing buried fuel tanks, contaminated soils, or legacy industrial sites located near the coast. Erosion can increase the risk of hazardous material releases, threatening environmental quality and public health, and complicating emergency response and cleanup efforts. Facilities handling hazardous materials lose natural protective buffers as shorelines retreat, increasing the likelihood of cascading impacts during severe weather events (USGS, 2023); (FEMA, 2021).

Variations in Mean Base Sea-Level

Sea level increase is a chronic and progressive coastal hazard that increases the frequency, depth, and duration of coastal flooding while accelerating erosion and shoreline instability. As relative sea levels rise, coastal communities experience more frequent high-tide flooding, expanded floodplains, and greater storm surge impacts. These changes place increasing stress on the y Lifelines that support public safety, economic stability, and emergency response, even in the absence of major storm events (FEMA, 2024).

- The Safety and Security Lifeline is affected as sea level rise increases the exposure of emergency facilities and evacuation routes to recurrent flooding. Police stations, fire stations, and emergency operations centers located in low-lying coastal areas may experience reduced functionality or loss of access due to chronic inundation. Rising seas can also compromise evacuation routes, bridges, and ingress/egress corridors, limiting the ability to conduct timely evacuations and delaying emergency response during hazard events (FEMA, 2021); (USGS, 2025).
- Sea level increase presents significant challenges to the Food, Water, and Shelter Lifeline. Potable water systems, wastewater treatment plants, and stormwater infrastructure are increasingly vulnerable to tidal flooding and saltwater intrusion as sea levels rise. These impacts can disrupt service delivery, degrade water quality, and increase maintenance and operational costs. In addition, repetitive flooding can damage residential structures, reduce housing availability, and increase demand for emergency shelter and long-term housing assistance, particularly in socially vulnerable communities (USGS, 2025).

- The Health and Medical Lifeline is impacted through both direct and indirect effects. Healthcare facilities located in flood-prone coastal zones may experience operational disruptions, equipment damage, or access constraints due to flood-impacted transportation networks. Frequent flooding can hinder patient movement, delay emergency medical services, and disrupt supply chains for pharmaceuticals and medical equipment. Public health concerns may also increase as rising groundwater and flooded sanitation systems elevate the risk of contamination and disease exposure (USGS, 2025; FEMA, 2024).
- Sea level increase also threatens the Energy Lifeline by increasing flood risk to power generation facilities, substations, fuel terminals, and transmission infrastructure located near the coast. Even minor but repeated flooding events can degrade electrical components and reduce system reliability, leading to power outages that affect residences, businesses, and critical facilities. Fuel distribution systems and ports may also experience operational interruptions, limiting fuel availability for generators, emergency vehicles, and recovery operations (FEMA, 2024).
- Communications Lifeline is vulnerable as increase in base sea level potentiates exposure of communications infrastructure, including cell towers, fiber-optic networks, and data facilities, to chronic flooding and corrosion. Disruptions to communications systems can impair emergency notification, 911 services, and interagency coordination. Repeated flood exposure without permanent mitigation measures may result in cumulative damage and decreased system reliability over time (FEMA, 2024).
- Transportation systems associated with the Transportation Lifeline are particularly sensitive to increase in base sea levels. Roads, bridges, ports, ferries, and coastal airports may experience more frequent closures or long-term service reductions due to flooding and infrastructure degradation. Transportation disruptions can isolate communities, delay emergency response, limit evacuation options, and impede the movement of goods, services, and recovery resources (USGS, 2025).
- Finally, increase in the mean base sea level can affect the Hazardous Materials Lifeline by increasing exposure of industrial sites, fuel storage areas, landfills, and wastewater facilities to flooding. Inundation of these sites raises the

potential for releases of hazardous substances, posing risks to human health, ecosystems, and drinking water supplies. Managing these risks becomes more complex as flood frequencies increase and protective buffers are lost (FEMA, 2021); (USGS, 2025).

4.15.2.3 Social Vulnerabilities

Long-term coastal dynamics can be not only a physical hazard but also a social stressor that disproportionately affects certain populations due to preexisting social, economic, and environmental conditions.

Low-income households are among the most socially vulnerable to long-term coastal dynamics. These populations are more likely to reside in older or lower-cost housing located in high-risk coastal areas and may lack the financial resources needed to invest in mitigation measures, such as structural reinforcement or relocation. As erosion or inward changes in shoreline progresses, declining property values can further reduce household wealth and limit access to insurance, credit, and recovery assistance, thereby prolonging vulnerability and recovery timelines (FEMA, 2023).

Housing insecurity is a significant concern associated with long-term coastal dynamics. Gradual land loss can render homes unsafe or uninhabitable, leading to chronic displacement rather than sudden disaster-related relocation. Renters are particularly vulnerable, as they often have limited control over mitigation decisions and may be displaced without sufficient notice or long-term relocation support. In communities with limited affordable housing options, erosion-related housing loss can increase overcrowding, homelessness, or permanent out-migration (FEMA, 2023).

Elderly individuals, people with disabilities, and those with chronic health conditions face heightened risks as coastal erosion disrupts access to essential services and infrastructure. Eroded or flooded roadways and transportation networks can isolate neighborhoods from healthcare facilities, pharmacies, grocery stores, and social services. These populations may also experience limited mobility or depend on in-home medical equipment, increasing their sensitivity to infrastructure disruptions associated with erosion (FEMA, 2023).

Communities that rely on coastal and marine resources for their livelihoods are also socially vulnerable to erosion. Fishing communities, small tourism-dependent businesses, and subsistence users may experience economic losses as shorelines

retreat, beaches narrow, and access to coastal infrastructure is reduced. These impacts can lead to job loss, reduced household income, and community-wide economic stress, particularly in rural and island settings where economic diversification is limited (USGS, 2023).

4.15.2.4 Natural and Cultural Resources

Long-term coastal dynamics rise can significantly impact natural resources by altering shorelines, degrading habitats, and disrupting ecological processes. As beaches, dunes, wetlands, and mangroves erode or become permanently inundated, the natural systems that provide storm protection, water filtration, and wildlife habitats are reduced or lost. These changes can lead to declines in biodiversity as plant and animal species lose critical breeding, feeding, and nesting areas. Saltwater intrusion caused by rising sea levels can also degrade freshwater ecosystems, affecting groundwater, estuaries, and coastal forests. Increased erosion can mobilize sediments and pollutants, diminish water quality and harming coral reefs and seagrass beds. Over time, the loss of natural coastal features reduces ecosystem resilience and increases inland exposure to flooding and storm impacts. (USGS, 2023)

Long-term coastal dynamics can also pose serious threats to cultural resources, particularly those located near shorelines. Historic buildings, archaeological sites, cemeteries, and cultural landscapes may be damaged or permanently lost as shorelines retreat and soils are destabilized. Gradual erosion can undermine foundations and expose artifacts, making sites vulnerable to destruction, looting, or environmental decay. As these resources are often irreplaceable, coastal erosion and sea level rise represent not only physical loss but also the loss of cultural memory and heritage passed through generations (USGS, 2023).

4.15.2.5 Future Conditions

As discussed in section 4.15.1 long-term coastal dynamics are understood to contribute to loss of shoreline, either due to coastal erosion or increases in mean base sea level. Specific mitigation actions to deal with expected future conditions will be included as part of Section 6.4.

4.16 Pandemic/Epidemic

4.16.1 Description (B1-a)

An epidemic occurs when the incidence of a disease or health-related event rises suddenly and significantly above what is expected in a specific community or region. According to the CDC, an epidemic represents a sudden increase in cases over the normal baseline in a population, and outbreaks—often used interchangeably—refer to such events in more limited geographic areas (CDC, 2012).

A pandemic is essentially an epidemic that has expanded to span multiple countries or continents, affecting a large portion of the global population. The CDC describes it as an epidemic with broad geographic spread, while the World Health Organization defines it as the worldwide transmission of a new disease to which people generally have little or no immunity (CDC, 2012).

These terms emphasize both the magnitude of cases and their geographical distribution: an epidemic is localized, but a pandemic reaches across international borders and impacts global public health systems. Consequently, emergency response strategies must escalate accordingly—from targeted regional interventions during epidemics to coordinated global action in pandemics.

4.16.1.1 Affected Area (B1-b)

This LHMP considers that all areas of the municipality are equally vulnerable to the Pandemic/Epidemic Hazard.

4.16.1.2 Risk Magnitude (B1-c)

Although all these events can result in loss of life and economic disruption, to distinguish between the following terms:

- Epidemic: refers to a sudden increase in the number of disease cases beyond what is normally expected within a specific population and geographic area.
- Outbreak: shares the same definition as epidemic but is typically used for a more localized area.
- Cluster: describes a grouping of cases in a particular place and time that appears to exceed the expected number, even if that expected number is unknown.

- Pandemic: refers to an epidemic that has spread across multiple countries or continents, usually affecting a large population (CDC, 2012).

4.16.1.3 Past Events (B1-d)

The following table listing epidemics and pandemics in Puerto Rico has been collected from various sources. This list does not intend to be exhaustive:

Table 50. Pandemics and Epidemic in Puerto Rico 1855 – 2020

Disease	Date	Classification	Description
Cholera Epidemic	1855 – 1856	Epidemic	Between 1855 and 1856, Puerto Rico suffered a major cholera outbreak that claimed over 25,820 lives, representing approximately 4–10% of the island's population at the time. (Vega Lugo, 2021)
Measles and Malnutrition	1917 – 1918	Epidemic	A severe measles outbreak occurred between 1917 and 1918, resulting in nearly 9,000 cases and approximately 2,000 deaths. High infant mortality—59% of deaths within six months were in children under two—was driven by malnutrition and poor living conditions (Rigau-Pérez & Vallejo – Calzada, 2020).
Spanish Flu (A/H1N1 influenza pandemic)	1918 – 1919	Pandemic	Puerto Rico was affected by the global A/H1N1 influenza pandemic, also known as the Spanish flu. Beginning around June 1918, community spread produced as many as 1,000 cases in four days in areas like Puerta de Tierra. Misdiagnosis as dengue initially obscured the true impact (Rosario Urrutia, 2021).
Poliomyelitis	1960	Epidemic	The 1960 polio epidemic in Puerto Rico was the most severe paralytic polio outbreak in the Western Hemisphere at the time. It impacted 68 of 76 municipalities, causing 495 cases of paralysis, predominantly among school-age children (Timothee, Morris, Filiberti, & Mainardi, 1963).
Dengue	2013, 2024	Outbreak	Dengue is endemic in Puerto Rico, with

Disease	Date	Classification	Description
			significant outbreaks occurring in 2013 and again in 2024. The 2024 outbreak triggered a public health emergency, with 6,291 confirmed cases, a 4.2% rate of severe dengue, and 11 deaths reported (Rodríguez, et al., 2024) (Ware-Gilmore, et al., 2025)
Chikungunya	2014	Epidemic	The first locally acquired chikungunya case in Puerto Rico was confirmed on May 5, 2014, triggering expanded surveillance efforts using Puerto Rico's dengue infrastructure. Between May 5 and August 12 of that year, 10,201 suspected cases (approximately 282 per 100,000 residents) were reported, of which 1,975 (68%) were laboratory-confirmed. During this period, four deaths were also recorded. (Sharp, et al., 2014)
Zika	2015 - 2016	Epidemic	The first locally transmitted Zika case in Puerto Rico was reported in December 2015. By April 2016, over 6,000 suspected cases had been evaluated, with 683 confirmed cases. Pregnant women and related neurological issues (e.g., Guillain-Barré syndrome) were of particular concern. (Thomas, et al., 2016) (Dirlikov, et al., 2016)
COVID - 19	2020 - 2022	Pandemic	See narrative below

COVID – 19 Pandemic

Puerto Rico confirmed its first COVID-19 case—a European tourist—on March 8, 2020, leading the governor to declare an emergency on March 12 and implement early measures including airport screening and mandatory isolation, as outlined in the Puerto Rico Department of Health's epidemic situation reports (PRDH, 2022), (COR3, n.d.). By April 6, 2022, official data reported 270,485 confirmed cases and 4,171 deaths due to COVID-19 in Puerto Rico, according to detailed government spreadsheets and dashboards maintained by the Puerto Rico Health Department (PRDH, 2022), (COR3,

n.d.).

The municipality experienced significant economic and social disruptions. A Bayesian analysis revealed a clear causal relationship between rising COVID-19 infections and increased unemployment, and engineering studies from the University of Puerto Rico–Mayagüez estimated that unemployment soared above 17%, also noting elevated operating costs for businesses due to personal protective equipment (PPE) and safety measures (Hernández – Padilla & Méndez-Piñero, 2020).

Subsequent public health research revealed widespread mental health consequences. One study found that 31% of healthcare workers scored in the range of depressive symptomatology following combined stress from prior disasters (e.g., hurricanes) and the pandemic; another identified high levels of anxiety (26.9%) and stress (69.9%) among physicians during the second COVID-19 wave (Hernández – Torres, et al., 2023), (Sánchez – Plazas, García – De Jesús, Martínez – González, Amaya – Ardila, & Almodóvar – Rivera, 2024).

4.16.1.4 Future Events Probability (B1-e)

Puerto Rico’s susceptibility to future pandemics or epidemics is underscored by its subtropical climate, population distribution, and healthcare infrastructure. A university-developed emergency preparedness model—commissioned by Puerto Rico’s Department of Health—simulated influenza pandemics and demonstrated how variations in disease transmissibility, healthcare capacity, and mitigation efforts can significantly influence outbreak trajectories and the likelihood of healthcare system overload. Furthermore, the U.S. Department of Health and Human Services’ Hospital Preparedness Program (HPP) in Puerto Rico operates under the Assistant Secretary for Preparedness and Response, with coordinated health care coalitions and special pathogen systems explicitly designed to reduce pandemic risk by strengthening surge capacity and infection-control readiness. These combined efforts reflect a data-driven recognition that, without sustained investment in public health infrastructure and preparedness modeling, Puerto Rico remains at an elevated probability for experiencing another epidemic or pandemic (Hirsh & Centeno – Marín, 2015), (ASPR, n.d.)

4.16.2 Risk Analysis (B2-a, B2-b)

4.16.2.1 Estimated Losses

The COVID-19 pandemic resulted in significant mortality across Puerto Rico, underscoring the importance of public health hazards in local mitigation planning. Official data from the Puerto Rico Department of Health indicate that COVID-19 mortality is tracked through an epidemiological surveillance system that compiles death certificate data and case investigations and is made publicly available through government data portals. At the territorial level, thousands of deaths have been attributed to COVID-19 since 2020, as reported in official datasets and federal summaries. However, cumulative mortality totals for individual municipalities, including Aguada, revision are not consistently published as single static figures in official reports. Instead, municipality-level death counts must be obtained by querying downloadable datasets provided by the Puerto Rico Department of Health, which allow users to filter results by municipality.

These datasets are considered provisional and subject to due to reporting delays and ongoing validation of death records, as acknowledged by public health authorities. Consequently, while Aguada-specific COVID-19 mortality was not recorded as fixed published figure. Based on the currently available data, the total number of COVID-19-related deaths in Aguada cannot be reliably determined.

4.16.2.2 Lifelines and Critical Infrastructure

In the event of a pandemic or epidemic, the most significantly affected lifeline is typically the healthcare and medicine lifeline. During widespread disease outbreaks, hospitals, clinics, and other healthcare facilities often face overwhelming demand for services. Surges in patient volume can exceed system capacity, leading to shortages of personal protective equipment (PPE), critical medical devices (such as ventilators during COVID-19), hospital beds, and qualified medical personnel. As resources are redirected to address the immediate public health emergency, non-urgent and even some essential non-related medical services may be postponed or delayed. Additionally, mortality management systems—including morgues, funeral services, and vital records processing—may experience severe strain during periods of elevated death rates.

However other lifelines can be affected such as the Food, Hydration and Shelter Lifeline, due to increase food insecurity from unemployment and economic shutdowns or closed or reduced shelters due to infection control requirements. The Safety and Security Lifelines can be affected by high absenteeism due to illness, quarantine or

caregiving responsibilities and increase levels of stress and burnout among first responders and law enforcement officers.

Other lifelines and critical infrastructures can be affected by increased demand, like increased residential water demand) or the lack of trained personnel to maintain existing operations.

4.16.2.3 Social Vulnerability

For this hazard, the entire population of Aguada is considered potentially vulnerable. However, access to healthcare services is an important factor influencing an individual's ability to prevent, respond to, and recover from pandemic or epidemic events. According to the 2019–2023 American Community Survey (ACS), uninsured residents are present across all age cohorts in Aguada, indicating that healthcare access challenges may affect multiple segments of the population. As shown in Table 51, the highest numbers of uninsured individuals are found among residents aged 26 to 34 years (± 343 persons), followed by those aged 35 to 44 years (± 272 persons) and 55 to 64 years (± 180 persons). These age groups may be more socially vulnerable during a pandemic or epidemic because limited healthcare coverage can create barriers to obtaining preventive care, medical treatment, and other essential health services during a public health emergency. Further information regarding social vulnerability can be found in Section 3.4.

Table 51. Number of People in Aguada without Healthcare Coverage

Age Cohort	Number of people uninsured
Under 6 years	± 30
6 to 18 years	± 29
19 to 25 years	± 91
26 to 34 years	± 343
35 to 44 years	± 272
45 to 54 years	± 124
55 to 64 years	± 180
65 to 75 years	± 100
75 years or older	± 36

4.16.2.4 Natural and Cultural Resources

The scientific literature shows that the COVID-19 Pandemic produced mixed environmental outcomes. While temporary lockdowns initially led to short-term improvements in air quality and reductions in greenhouse gas emissions in many regions, broader evidence suggests that the pandemic also generated significant negative environmental impacts.

These impacts included increased pollution from the widespread use of personal protective equipment, deforestation, illegal poaching and logging, overfishing, and disruptions to conservation programs and projects. The findings also note that the spread of pandemics may be intensified by environmental pollution and rapid global population growth (Muche, Yemata, Molla, Muasya, & Tsegay, 2022) (Guo & Lee, 2021).

At the same time, despite these adverse impacts, the period of reduced human activity—often referred to as the *anthropause*—also produced several positive effects on natural resources. These included short-term reductions in indoor and outdoor air pollutants including PM_{2.5}, PM₁₀, NO₂, SO₂, CO, and CO₂, as well as a decrease in noise pollution from ships, boats, vehicles, and aircraft. Collectively, these changes benefited aquatic ecosystems and water quality, influenced bird behavior, supported wildlife biodiversity, and contributed to temporary ecosystem recovery (Muche, Yemata, Molla, Muasya, & Tsegay, 2022).

When it comes to cultural and heritage sites, a report from UNESCO notes that the crisis has produced both negative and positive effects across different types of World Heritage properties (UNESCO, 2021). The sudden cessation of travel and tourism disrupted visitor flows and eliminated a critical source of revenue for many sites, where tourism income is essential to supporting conservation activities, routine maintenance, and staff salaries. Local communities surrounding these properties were similarly affected, with widespread loss of employment and income.

Conversely, in some cases, the reduced level of human activity enabled rehabilitation and restoration efforts to proceed more efficiently, while anthropogenic pressures were temporarily reduced across many natural areas. This contrast highlights the diverse and uneven impacts of the crisis on World Heritage properties. At the same time, it highlights opportunities to build upon the environmental benefits observed during reduced activity periods, while advancing targeted research, sustainable tourism strategies, and long-term recovery planning (Guo & Lee, 2021) (Guibert & Hyde, 2021), (UNESCO, 2021).

4.16.2.5 Future Conditions (E1-a)

Puerto Rico faces structural and environmental conditions that elevate its exposure and vulnerability to future pandemics relative to many mainland U.S. locations. As a tropical island with high population density in urban corridors, frequent international travel, and climatic conditions favorable to vectors and pathogens, Puerto Rico is particularly susceptible to emerging and re-emerging infectious diseases, especially those with zoonotic or vector-borne origins. The CDC and peer-reviewed research document ongoing transmission of diseases such as dengue and previous outbreaks of Zika and Chikungunya, demonstrating the island's continued exposure to pathogens with outbreak and epidemic potential. This exposure holds regardless of the development pattern of the municipality.

4.17 Hazard Prioritization

After receiving feedback from the public and stakeholders (see Section 2.6–2.7) along with their own expertise the planning committee has determined that the following is the prioritization for the hazard discussed in this LHMP.

Table 52. Hazard Prioritization

Hazard	Priority
Earthquake	Mid Priority
Landslide	High Priority
Tsunami	Mid Priority
Flooding	High Priority
Tropical Cyclones/Extreme Winds	High Priority
Storm Surge	Low Priority
Extreme Heat	Mid Priority
Drought	High Priority
Wildfire	Mid Priority
Long-Term Coastal Dynamics	High Priority
Pandemics	Mid Priority

4.18 Planning Mechanism

Understanding and recognizing regulatory and planning capacities enables more effective management of land use and economic growth. These capacities consist of the legal frameworks and public policy provisions that influence land use to guide sustainable development, while also supporting actions that mitigate the vulnerability

of communities and their resources to natural hazards.

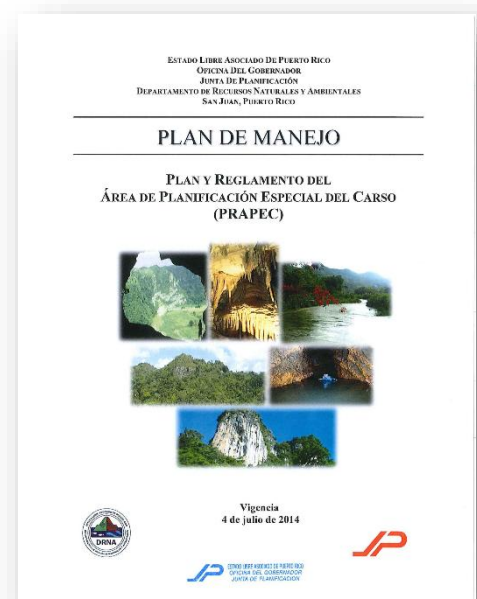
Besides the Public Policies already discussed in Section 1.1, what follows is a list in chronological order of the regulatory and planning mechanisms available to the municipality for the implementation of this LHMP.

4.18.1 Karst Special Planning Area Plan and Regulation (PRAPEC, by its Spanish Acronym) – 2014)

In compliance with Act 292-1999, this plan and regulation establish two overlayed districts in the karst zones of Puerto Rico. The Restricted Karst Special Planning Area (APE-RC) overlayed district aims to protect the land within the Restricted Karst Area. According to Act 292-1999, lands under this district cannot be used for the extraction of materials from the earth's crust, except in cases where such activities had already been recognized by the competent authorities at the time of the adoption of PRAPEC. Additionally, the APE-RC imposes other restrictions, such as prohibitions on subdivision in certain underlying districts.

On the other hand, the Special Planning Area for the Karst Zone (APE-ZC) overlayed district includes lands within the karst physiography that are not part of the APE-RC. Its purpose is to allow the extraction of materials from the earth's crust for commercial purposes under appropriate conditions, in areas of the karst zone that are not within the APE-RC, and to address lands that, although part of the karst physiography, are not included in the restricted area.

Figure 34. PRAPEC Coversheet



4.18.2 Joint Regulation for the Evaluation and Issuance of Permits Related to Development, Land Use, and Business Operations (2023)

The Joint Regulation for the Evaluation and Issuance of Permits Related to Development, Land Use, and Business Operations (*Reglamento Conjunto* in Spanish) is a regulatory instrument created by the Planning Board in compliance with Law No.

161, as amended. Its main purpose is to regulate land use, territorial planning, and the granting of permits related to development, construction, and business operations within a uniform and centralized framework. The Joint Regulation aims to harmonize public policy on land use planning with the principles of sustainable development, seeking a balance between economic growth, environmental protection, and social well-being. This regulation establishes the rules to classify land, define zoning districts, regulate zoning, and determine the permitted uses in each category. Additionally, it sets the procedures to evaluate projects, issue permits, and monitor compliance with the applicable provisions. Its purpose is to provide a uniform regulatory framework for the evaluation and issuance of permits, ensure the proper use of land, protect natural resources, and facilitate economic development under criteria of competitiveness and sustainability, integrating planning with permit management.

Figure 35. Joint Regulation Cover



Of particular importance in the Joint Regulation is the zoning district *Distrito de Riesgo para Espacios Abiertos* – Open Space (RE-A).¹³ The RE-A zoning district is established to identify lands designated as open space in accordance with federal regulations (44 CFR Part 80) or another federal program, due to the presence of a risk condition resulting from a natural event. These spaces may include, but are not limited to, severe flooding and landslides. There are conditions in these areas that are unfavorable or harmful to health, safety, or general welfare, and there may be a risk of loss of life and property. Land within this district may be susceptible to one or more of the identified hazards.

The purpose of the district is to preserve the open space condition established in perpetuity by federal regulation, which the government or the community must uphold, with the objective of protecting health, life, and property; preventing severe losses and repetitive use of affected properties; reducing the investment of public and federal funds in mitigation; and limiting rescue efforts, among other goals.

¹³ Joint Regulation Rule 6.1.30

4.18.3 Special Flood Hazards Areas Regulation (2021)

The 2021 regulation was adopted by the Puerto Rico Planning Board under its authority from Public Law No. 75 of 1975 and Public Law No. 3 of 1961 to control development in flood-prone zones. It aligns Puerto Rico's floodplain management requirements with the minimum standards of the National Flood Insurance Program (NFIP), administered by FEMA. The regulation establishes updated criteria for construction, land use, and development within Special Flood Hazard Areas (SFHAs), including requirements such as elevating structures above Base Flood Elevation and submitting technical certifications. It applies to new construction, substantial improvements, and land-use changes across designated flood zones such as AE and VE, using FEMA Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FIS) for zone identification. The revision clarifies and expands regulatory provisions to enhance public safety and prevent harmful development in high-risk areas.

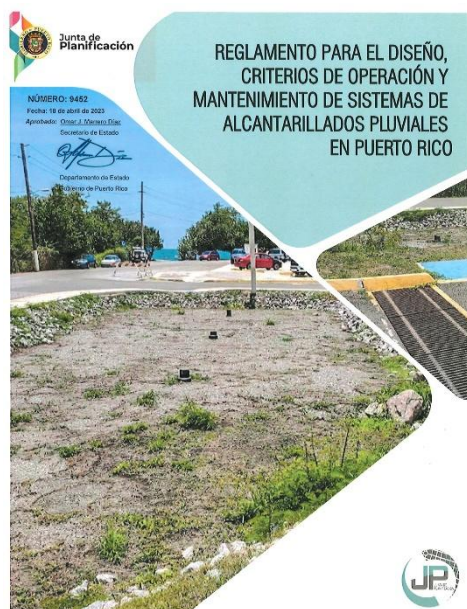
4.18.4 Puerto Rico Building Code

The Puerto Rico Building Code sets minimum requirements for the design, construction, modification, and upkeep of buildings to ensure the safety, health, and well-being of the public. It is derived from nationally and internationally recognized model codes and is updated periodically to incorporate improvements in construction practices and lessons learned from past hazard events. The code includes provisions addressing structural safety, fire protection, accessibility, energy conservation, and resistance to natural hazards such as earthquakes, hurricanes, floods, and strong winds. Adherence to the Building Code is mandatory for all new construction and substantial renovations throughout Puerto Rico. Enforcement is carried out through local permitting, planning review, and inspection processes to verify compliance with established standards. Overall, the Puerto Rico Building Code is a key instrument for advancing resilient, safe, and sustainable development across the island.

4.18.5 Regulation for the Design, Operation Criteria and Maintenance of Stormwater Systems in Puerto Rico

Adopted in 2023 as Planning Regulation No. 40, this regulation updates and replaces the island's outdated 1975 standards to address

Figure 36. Regulation 40 Cover



current engineering practices, environmental considerations, and increased flood risk. The regulation is designed to provide developers, engineers, contractors, and municipalities with modern technical criteria for designing, operating, and maintaining public and private stormwater systems, incorporating updated scientific knowledge and methodologies necessary for managing stormwater infrastructure under present-day conditions. Its objectives include minimizing flood-related damage, improving the capture and management of runoff, reducing impacts to water resources and ecosystems, and supporting safer, more resilient community development. The regulation integrates risk management principles and aligns with Puerto

Rico's climate adaptation policies, requiring consideration of urban flooding, karst hydrology, low-impact development practices, and stormwater control structures such as retention and detention systems. It also establishes minimum design considerations for all land development projects and provides a comprehensive framework for planning, monitoring, and maintaining stormwater systems across the island.

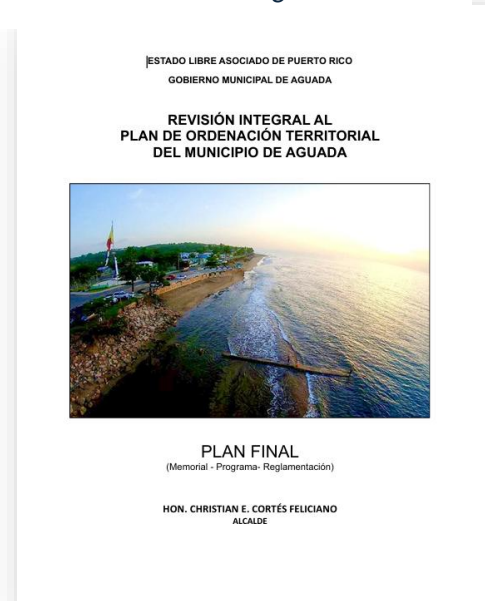
4.18.6 Aguada Territorial Plan (2012)

As established by the Puerto Rico Municipal Code, the Municipality of Aguada adopted an updated Territorial Plan (Plan de Ordenación Territorial, POT) in December 2024. The POT is a strategic and comprehensive land use planning instrument that guides future growth, development, conservation, and infrastructure decisions throughout the municipality. The plan establishes policies, objectives, and implementation strategies to support Aguada's long-term physical, environmental, and socioeconomic development.

- The 2024 Territorial Plan was developed to:
- Incorporate planning policies, strategies, and recommendations adopted by the Puerto Rico Planning Board since the previous Territorial Plan update.

- Integrate applicable legislation, regulations, and public policy updates affecting land use and municipal planning.
- Evaluate current demographic, economic, housing, and land development trends within the municipality.
- Address lessons learned and planning considerations associated with Hurricanes Irma and María and other natural hazards affecting Puerto Rico.
- Incorporate hazard mitigation, climate adaptation, and community resilience principles into future planning and development decisions.
- Support the municipality's vision for sustainable growth, environmental stewardship, economic development, and quality of life.
- Establish updated land use policies and development strategies that reflect current conditions and anticipate future needs.

Figure 37. Aguada Land Use Plan Cover Page



4.18.7 Aguada Emergency Operation Plan

This Emergency Operation Plan (EOP) describes how emergency operations are structured through the Incident Command System, enabling unified command and efficient allocation of resources. It details the activation levels of the Municipal Emergency Operations Center, which escalates from routine monitoring to full 24/7 multi-agency disaster response. The municipality highlights the importance of interagency collaboration, including coordination with state and federal agencies when local capabilities are exceeded. Community involvement, public information, and support for vulnerable populations—such as individuals with disabilities, children, and the elderly—are essential components woven into all phases of emergency management. Additionally, the plan incorporates long-term recovery strategies, emphasizing damage assessments, restoration of critical services, and alignment with federal assistance processes. Ultimately, it presents a structured, community-centered approach to ensure Aguada can respond to, withstand, and recover from a wide range of emergencies.

4.18.8 National Flood Insurance Program

The National Flood Insurance Program falls within the category of planning mechanisms, as it imposes certain floodplain management requirements. FEMA provides flood insurance to communities that are following the NFIP criteria. This includes adopting and enforcing floodplain management practices that promote appropriate development in these flood-prone areas.

The National Flood Insurance Program of the Federal Emergency Management Agency allows homeowners, business owners, and renters in participating NFIP communities to purchase federally backed flood insurance. This insurance provides assistance to help cover the costs of repairing damage caused by flooding to buildings and their contents. This is an insurance program established to help property owners, renters, and businesses recover more easily and at a lower cost. Likewise, the program aims to reduce the impact of flooding on both public and private structures. These efforts help mitigate the effects of flooding on new and improved structures within each community.

The NFIP has several components, including:

- Floodplain management — for which the community must adopt and enforce measures for managing flood-prone lands in accordance with NFIP regulations;
- The preparation of Flood Insurance Rate Maps (FIRMs); and
- Flood insurance.

The Municipality of Aguada has a collection of FIRM maps that can be consulted to determine whether your property is in a high-risk area or in a low- to moderate-risk zone. FIRMs refer to the official map developed and approved by FEMA and adopted by the Puerto Rico Planning Board to designate areas at risk of a 100-year flood (or a 1% annual chance of occurrence). In addition, these maps serve as a tool for managing special areas due to their susceptibility to flooding events.

While the Write Your Own Program (WYO) began in 1983 as a partnership between insurance companies and FEMA. This arrangement allows property and casualty insurance companies to underwrite and service federal flood insurance policies in their own company name. A key feature of this type of policy is that all companies participating in the WYO program provide the same coverage, and their rates must comply with NFIP rules and regulations.

Communities, for their part, adopt and require compliance with the NFIP's minimum

standards for construction and development in designated Special Flood Hazard Areas. However, many communities seek to achieve a higher level of safety and protection for their residents beyond the NFIP minimum standards. For this purpose, communities have the option of participating in the NFIP's Community Rating System (CRS), which allows them to obtain reductions in flood insurance premiums.

This is because the CRS recognizes additional community efforts to: 1) Reduce flood damage to insurable property; 2) strengthen and support NFIP insurance provisions; and 3) encourage a comprehensive approach to floodplain management. These additional efforts provide residents with greater safety, reduce property damage, enhance community resilience, and promote a better quality of life. The municipality's participation in the NFIP will be discussed in Section 6.5.

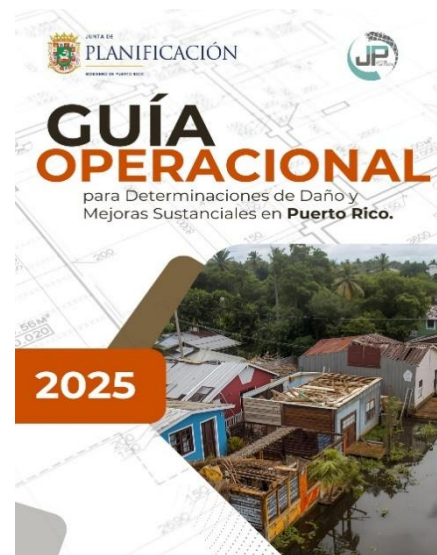
4.18.9 National Pollutant Discharge Elimination System (NPDES)

The NPDES is a program authorized under the United States Clean Water Act and administered by the Environmental Protection Agency (EPA). This program requires Municipal Separate Storm Sewer Systems (MS4s) to obtain a permit for the discharge of stormwater into water bodies. In the case of Puerto Rico, the EPA issued a general permit in 2016, under which municipalities can obtain coverage by submitting a Notice of Intent (NOI) and adopting a Stormwater Management Program (SWMP). If any of the mitigation measures listed in Section 6.5 modify the NOI or the SWMP, they will be properly amended.

4.18.10 Operational Guidelines for Determining Damages and Substantial Improvements in Puerto Rico (2025)

The Floodplain Administrator or the Participating Community may review, require, and audit permits in accordance with the provisions of Act No. 3 of September 27, 1961, known as the “Floodplain Building Control Act”; Act No. 75, the “Puerto Rico Planning Board Organic Act”; Act No. 161 of December 1, 2009, as amended, the “Puerto Rico Permit Process Reform Act”; and Act No. 38 of June 30, 2017, the “Uniform Administrative Procedure Act of the Government,” as amended, and in compliance with the regulations of the National Flood Insurance Program (NFIP) of the Federal Emergency Management Agency (FEMA), Title 44 of the Code of Federal Regulations (CFR), Part 60.3 [d, e, and Subpart B], and its related sections.

Figure 38. Operational Guidelines



As of the effective date of this guidance, an evaluation of substantial damage or substantial improvement will be required as part of the permitting requirements in Special Flood Hazard Areas. The Floodplain Administrator will require that both new structures and substantial improvements be constructed in a manner that minimizes or prevents damage during a regulatory flood.

4.18.11 Green Infrastructure and Nature Based Solutions

Section 502 of the United States Clean Water Act defines green infrastructure as the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvesting and reuse, or landscaping to store, infiltrate, or evapotranspiration stormwater and reduce flows to sewer systems or surface waters.

Green infrastructure is a cost-effective and resilient approach to managing wet weather impacts that provide many benefits to the community. While conventional single-purpose gray stormwater infrastructure (such as pipe drainage and water treatment systems) is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while providing environmental, social, and economic benefits.

Stormwater runoff is a major cause of water pollution in urban areas. When it rains on rooftops, streets, and parking lots in cities and suburbs, the water cannot soak into the

ground as naturally would. Instead, stormwater drains through gutters, storm sewers, and other collection systems and is discharged into nearby water bodies. This runoff carries trash, bacteria, heavy metals, and other pollutants from the urban landscape. Higher flows resulting from heavy rainfall can also cause erosion and flooding in urban streams, damaging the environment, property, and infrastructure.

When rain falls in undeveloped natural areas, the water is absorbed and filtered by soil and vegetation. Stormwater runoff is cleaner and less problematic. Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes needed to manage water and create healthier urban environments. At the municipal scale, green infrastructure is a network of natural areas that provide habitat, flood protection, cleaner air, and cleaner water. At the neighborhood, development, or sector scale, managing stormwater systems in a way that mimics natural processes help absorb and store runoff that can otherwise cause localized flooding (EPA, 2019).

Some green infrastructure measures that may be considered to mitigate flooding problems include:

- Rainwater harvesting
- Rain gardens (bio-retention/bio-infiltration)
- Urban rain gardens (“planter boxes”)
- Bioswales
- Porous pavements
- Green streets
- Green parking lots
- Green roofs
- Land conservation
- Creation or maintenance of urban tree canopy
- Wetland restoration
- Riparian area rehabilitation
- Sand dune restoration, among others.

The Municipality will consider green infrastructures measures when developing or championing flood control measures with the state or the federal government. In addition to flood control, green infrastructure provides benefits such as improved water quality, enhanced water supply, reduced stormwater management costs (public and private), improved habitat quality, increased spaces for recreation and physical activity, job creation in the maintenance of natural areas, and increased property values (EPA, 2019).

4.18.12 Four – Year Investment Program

The Four-Year Investment Program 2022–2023 to 2025–2026 (hereinafter, the PICA) is a short- and medium-term planning instrument designed to guide, coordinate, and direct public investments during the period it covers. Through this instrument, the Planning Board integrates the efforts of various government entities aimed at improving the quality of life of the people of Puerto Rico, in line with established public policies.

The Framework of Reference for the Four-Year Investment Program for the period 2022–2023 to 2025–2026 guides agencies and public corporations in preparing their investment and capital improvement programs. The framework includes a demographic and socioeconomic profile of Puerto Rico as a whole and by regional organization, a diagnosis of the recent performance of the economy, and information on development patterns and priority projects for the competitive Puerto Rico to which all aspire.

The full PICA document for the 2022–2023 to 2025–2026 period incorporates all information on capital improvement projects to be carried out by government entities. It includes a detailed analysis of the distribution of recommended resources by program areas and the origin of those resources. This analysis is the result of an integration process designed to guide budget recommendations formulated by the Office of Management and Budget regarding the Annual Capital Improvements Program included in Puerto Rico’s budget.

This program serves as a short- and medium-term planning tool to guide, coordinate, and direct public investments during its period of effectiveness. It uses Puerto Rico’s demographic and socioeconomic profile, along with a regional analysis as established by the Planning Board (JP, 2022).

With respect to the municipality’s Hazard Mitigation Plan, the PICA is used to integrate information on the current performance of Puerto Rico’s economy, including data on public debt and development trends, as well as projects designated as priorities for implementation on the Island. Within this framework, the PICA provides municipalities with information from government entities regarding funding allocations and investments in improvements they are responsible for implementing, which contribute to municipal efforts to mitigate natural hazards.

As part of the projects influencing all Functional Areas of Puerto Rico, the review of municipal Mitigation Plans is included. The Planning Board was designated by the Government Authorized Representative (GAR) as the agency responsible for reviewing and developing Hazard Mitigation Plans in coordination with the 78 municipalities¹⁴.

¹⁴ GAR function is currently held by COR3

5. Municipal Capacities

5.1 Regulatory and Planning Capacities (C1-a)

Understanding and recognizing regulatory and planning capacities enables more effective management of land use and economic growth. These capacities consist of the legal frameworks and public policy provisions that influence land use to guide sustainable development, while also supporting actions that mitigate the vulnerability of communities and their resources to natural hazards.

5.2 Technical and Administrative Capacities (C1-a)

The Municipality of Aguada is well staffed to implement this LHMP. The Municipality has a Planning office. Copy of this municipal organigram can be found as part of Appendix E.

Table 53 shows the Municipality's Technical and Administrative Capacity

Table 53. Municipal Technical and Administrative Resources

Personnel Team / Resources	Yes	No	Future Positions	Department or Agency	Opportunities to Integrate into LHMP	Comments
Planners with experience in land use and mitigation	x		N/A	N/A	N/A	Currently the municipality has a planning department. Any planning related issue is worked through the planning office.

Personnel Team / Resources	Yes	No	Future Positions	Department or Agency	Opportunities to Integrate into LHMP	Comments
Engineers or professionals trained in construction practices related to buildings and infrastructure		X	Through contract services if needed	N/A	N/A	Currently the municipality does not have this staff. If the need arises this position will be procured by external professional services.
Planners or engineers with a broad understanding of natural hazards		X	Through contract services if needed	N/A	N/A	Currently the municipality does not have this staff. If the need arises this position will be procured by external professional services.
Emergency Manager	X		N/A	Municipal Emergency Management Office, Department of Public Safety	The LHMP may be used to update the EOP	None
Scientists familiar with natural hazards		X	Through contract services if needed	University of Puerto Rico, Puerto Rico Seismic Network, other universities in Puerto Rico		Currently the municipality does not have this staff. If the need arises this position will be procured by external professional services.

Personnel Team / Resources	Yes	No	Future Positions	Department or Agency	Opportunities to Integrate into LHMP	Comments
Personnel with expertise or education regarding the vulnerabilities and natural hazards affecting the community	X		Community Representative	N/A	N/A	
Resource development staff or grant writers		X	Director of Municipal Federal Programs	Municipal Federal Programs Office	This staff may write and administer grants to cover the mitigation strategies mentioned below.	N/A

5.3 Financial Capacity (C1-a)

The Municipality has experience administering federal funds from various streams and maintains a dedicated office responsible for the administration and oversight of federally funded programs.

5.3.1 FEMA Funding Streams

For hazard mitigation projects the municipality has identified the following FEMA – administered possible funding streams which it could draw from.

Stafford Act – Section 404

Section 404 refers to Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, which authorizes the Hazard Mitigation Grant Program (HMGP), administered by FEMA. Its primary purpose is to reduce future disaster losses by funding long-term mitigation projects after a major disaster is declared.

Under Section 404, funding is made available to states, territories, tribes, and local governments to implement mitigation measures that lessen the impacts of future hazards such as floods, earthquakes, hurricanes, wildfires, and droughts. Unlike Section 406, Section 404 projects do not have to be tied to facilities that were damaged by the declared disaster. This allows communities to take a proactive approach by investing in mitigation actions that address known risks before damage occurs.

Eligible projects under Section 404 may include activities such as elevation or acquisition of flood-prone structures, drainage improvements, seismic retrofits, safe rooms, wildfire mitigation measures, and hazard mitigation planning. Projects must be cost-effective, technically feasible, and consistent with an approved Hazard Mitigation Plan. The program typically provides up to 75 percent federal funding, with the remaining share provided by non-federal sources.

Under Section 404 is also the Hazard Mitigation Grant Program (HMGP) that can support plan development, data collection, risk assessments, and engagement activities required to maintain FEMA approval following a presidential disaster declaration.

Stafford Act – Section 406

Section 406 of the Stafford Act supports mitigation projects by allowing hazard-mitigation measures to be incorporated directly into the repair or replacement of public facilities damaged during a declared disaster. This provision enables communities to strengthen damaged infrastructure against future hazards, such as elevating flood-damaged buildings, reinforcing structures to withstand high winds, or improving drainage systems during repairs. Mitigation measures funded under Section 406 must be cost-effective and directly related to the damaged facility. By integrating mitigation into recovery activities, Section 406 helps reduce the likelihood of repetitive damage and future repair costs. Overall, it ensures that rebuilding efforts contribute to long-term resilience rather than simply restoring pre-disaster conditions.

Stafford Act – Section 428

Section 428 of the Stafford Act can support mitigation projects by allowing communities to integrate hazard-resilient and risk-reduction measures directly into disaster recovery projects funded through FEMA's Public Assistance Program. Through

its alternative procedures, Section 428 enables flexible project design, fixed-cost funding, and consolidation of damaged facilities, making it easier to incorporate mitigation improvements such as relocation, elevation, floodproofing, or structural hardening. Applicants may also reinvest cost savings from efficiently managed projects into additional mitigation features, if project objectives are met. By emphasizing outcomes rather than strict cost reimbursement, Section 428 encourages rebuilding that reduces future risk rather than simply restoring pre-disaster conditions. This approach allows mitigation to become an integral part of recovery, strengthening resilience and reducing the likelihood of repetitive losses.

Flood Mitigation Assistance Program

The Flood Mitigation Assistance (FMA) Program reduces flood hazards by providing funding to help communities identify and implement measures that lessen long-term flood risk to National Flood Insurance Program (NFIP) insured properties. The program focuses on projects such as elevating, acquiring, relocating, or floodproofing flood-prone structures, with priority given to repetitive loss and severe repetitive loss properties. By mitigating flood damage before disasters occur, FMA helps protect lives and property, reduces future flood insurance claims, and lowers the overall cost of disaster assistance. The program encourages proactive risk reduction by aligning mitigation investments with floodplain management and local hazard mitigation planning.

Stafford Act – Section 203 (BRIC)

The Building Resilient Infrastructure and Communities (BRIC) program supports mitigation projects by providing pre-disaster funding to help communities reduce risks from natural hazards before disasters occur. Administered by FEMA, BRIC focuses on long-term, cost-effective investments that enhance the resilience of critical infrastructure, lifelines, and communities. The program funds activities such as infrastructure retrofits, flood control projects, seismic upgrades, and nature-based solutions, as well as hazard mitigation planning and capacity building. BRIC emphasizes innovative, large-scale projects that address multiple hazards and provide measurable community benefits. By investing in mitigation prior to disasters, the BRIC program helps protect lives and property, reduce future disaster costs, and support more resilient and sustainable development.

5.3.2 Non-FEMA Federal Funding Streams

Non-FEMA federal Funding Streams can include:¹⁵

CDBG-DR

The Department of Housing and Urban Development's Community Development Block Grant-Disaster Recovery (CDBG-DR) program can fund hazard mitigation planning and projects by supporting activities that reduce long-term disaster risk and address unmet recovery needs following a major disaster. CDBG-DR funds may be used to develop or update hazard mitigation plans, conduct risk assessments, and support resilience and mitigation planning efforts that guide future investments. In addition, the program can finance mitigation projects such as drainage improvements, flood control infrastructure, elevation or acquisition of flood-prone properties, utility hardening, and other measures that reduce vulnerability to natural hazards. Unlike some recovery programs, CDBG-DR allows communities to target mitigation actions even if facilities were not damaged in the most recent disaster, as long as the activities address identified risks.

CDBG-MIT

The Department of Housing and Urban Development's Community Development Block Grant-Mitigation (CDBG-MIT) program supports hazard mitigation planning and projects by providing federal funding specifically dedicated to reducing future disaster risks in communities that have experienced major disasters. CDBG-MIT funds can be used for mitigation planning activities such as risk assessments, data analysis, and development of strategies that guide long-term resilience investments. The program also finances a wide range of mitigation projects, including flood risk reduction, stormwater management, wildfire mitigation, resilient infrastructure upgrades, and nature-based solutions. CDBG-MIT emphasizes addressing identified vulnerabilities and repetitive loss areas, even if they were not directly damaged in a recent disaster. By focusing on forward-looking risk reduction, the program helps communities proactively adapt to climate impacts and future hazards. Overall, CDBG-MIT integrates mitigation into long-term recovery and development efforts, strengthening community resilience and reducing future disaster losses.

It should be noted that CDBG-DR and CDBG-MIT differ primarily in their purpose and

¹⁵ Please note that the following list is not intended to be exhaustive.

how they support hazard mitigation planning and projects. CDBG-DR focuses on post-disaster recovery, with mitigation activities integrated into rebuilding efforts to address unmet needs and reduce future risk as communities recover. Under CDBG-DR, mitigation planning and projects must be closely tied to disaster recovery goals and justified by disaster impacts or recovery assessments. In contrast, CDBG-MIT is specifically dedicated to hazard mitigation and long-term risk reduction, allowing communities to fund mitigation planning and projects even if areas or facilities were not damaged in the most recent disaster.

Resilience and Emergency Relief Programs

The Federal Highway Administration (FHWA) Resilience and Emergency Relief Programs support Hazard Mitigation Plans by promoting the identification and reduction of risks to transportation infrastructure from natural hazards. Through the Emergency Relief Program, FHWA allows mitigation and resilience measures—such as improved drainage, roadway elevation, and bridge reinforcement—to be incorporated into post-disaster repairs. FHWA resilience initiatives also encourage vulnerability assessments and risk-based planning that align with the risk assessment and mitigation strategy components of FEMA-approved HMPs. By integrating hazard mitigation and climate resilience into transportation planning, these programs help ensure that roads and bridges are addressed as critical lifelines. Overall, FHWA programs complement Hazard Mitigation Plans by supporting transportation-focused mitigation actions that reduce future disruption and repair costs.

National Resource Conservation Service

The Environmental Quality Incentives Program (EQIP) and the Watershed and Flood Prevention Operations (WFPO) program support hazard mitigation projects by addressing risks at the landscape and watershed scale through conservation and infrastructure improvements. EQIP, administered by the USDA Natural Resources Conservation Service (NRCS), provides financial and technical assistance to landowners to implement conservation practices that reduce erosion, manage runoff, improve soil health, and mitigate risks from flooding, drought, and wildfires. These practices—such as vegetation management, streambank stabilization, and water retention—help lessen downstream flood impacts and enhance resilience to climate variability. The Watershed and Flood Prevention Operations program support larger-scale mitigation through structural and non-structural measures, including small dams, floodwater retarding structures, channel improvements, and watershed planning. Together, these programs reduce hazard exposure upstream, protect

communities and infrastructure downstream, and integrating natural resource management into long-term flood and drought mitigation strategies.

5.3.3 Local Funds

Aguada, like other municipalities in Puerto Rico, receives revenue from the Municipal Revenue Collection Center (MRCC). Other funding sources include revenue from the Sales and Use Tax (IVU, by its Spanish acronym), legislative funds that might be assigned from time to time and other sources. Depending on the state of municipal finances, the municipality might determine that there are some funds that can be used to pay for or cover local funds match for mitigation projects.

However, most major capital improvement projects depend on federal funds transfers. The use of federal funds varies widely from year to year. In some cases, these funds are used to cover costs associated with the creation and monitoring of specific programs (for example, Section 8 or housing programs). In other cases, the funds are used to finance major capital improvement projects.

5.4 Outreach and Communications Capacity (C1-a)

Building robust outreach and communication capacity is essential to the successful implementation of a Hazard Mitigation Plan, as effective risk communication enables residents to recognize their risks, actively participate in planning processes, and make informed decisions to reduce potential impacts. FEMA guidance underscores the importance of early and thoughtfully designed engagement strategies to ensure that key stakeholders exchange information at the right time, promoting shared awareness of hazards and broad support for mitigation actions. Communication is a fundamental preparedness capability because it provides timely, practical information that helps individuals and communities act to limit harm. Research further demonstrates that outreach efforts are most successful when messages are clearly defined, customized for specific audiences, and conveyed through trusted sources. Communities that prioritize outreach—by collaborating with local leaders, leveraging a variety of communication channels, and tailoring messages to different population groups—tend to achieve higher public involvement and more effectively incorporate community feedback into hazard mitigation planning. These practices ultimately contribute to more effective plans and more resilient communities (FEMA, 2025).

The Municipality demonstrates adequate capacity to conduct effective outreach and communication activities. The Office of Planning is responsible for coordinating these efforts, and an organizational chart for this office is provided in Appendix E. The Municipality utilizes both social media platforms for real-time communication and traditional methods to disseminate information to the public. In addition, the Planning Office administers the Community Board responsible for land-use decisions, which is largely composed of municipal residents. This board serves as an important forum for public engagement and provides an opportunity to further expand and strengthen the Municipality's outreach and communication capacity.

Table 54 details the communication tools available to the municipality.

Table 54. Outreach and Communications Tools

Tool or resource	Available (Y/N)	Description	Agency in Charge	Comments
Social Media	Y	Facebook	Major Office	Municipality shared progress information regarding the Plan update and published the invites for the outreach activities.
News Paper	Y	Although the municipality has the capacity and standard practice to publish on newspapers, for this revision the planning board	Planning Board	Public announcements were made for community outreach meetings by the planning board, and the municipality was responsible for sharing it through social media.
Radio or Podcast	Y	Weekly segment on Radio Una 1340	Major Office	Public announcement was made for the community meetings outreach.
Web Page	Y	www.poraguadaes.com		
Publisher or capacity to publish material	Y			

5.5 Capacity Development (C1-b)

Strengthening institutional and technical capacity is vital to the successful implementation of a Hazard Mitigation Plan, as communities must have the expertise, resources, and organizational frameworks needed to move from planning to sustained risk-reduction actions. FEMA guidance stresses that effective mitigation planning relies on well-coordinated teams, access to reliable technical data, and the ability to collaborate across agencies and stakeholders—all of which directly affect the execution of mitigation strategies. National evaluations have shown that local and state governments often face challenges in implementing mitigation projects not due to a lack of commitment, but because of limited technical assistance, constrained administrative capacity, and insufficient engagement with federal support programs. Studies focused on low-capacity communities further demonstrate that gaps in technical knowledge, training, and leadership involvement can significantly hinder mitigation outcomes. These findings highlight the importance of strengthening workforce skills, enhancing guidance and tools, and reinforcing institutional support to achieve long-term resilience.

The Municipality continues to enhance its mitigation capacity by retaining qualified professionals as staff or contractors as needs arise. It also actively participates in training and continuing education opportunities offered through Commonwealth agencies and academic institutions to build and maintain the technical and institutional expertise necessary to support hazard mitigation efforts.

6. Mitigation Action Plan

The goals, objectives, and mitigation actions outlined in this Plan are based on discussions held by the designated Mitigation Plan Committee, as well as the public-participation activities conducted to date.

6.1 Mitigation Goals (C3-a)

6.1.1 Mitigation Goals and Objectives

After reviewing the information presented in the risk assessment and considering community input, the following mitigation objectives for Aguada can be identified:

- Implement programs and policies to reduce the impact of natural disasters on the population, property, and infrastructure, to protect against future disaster development.
- Increase the municipality's capacity to implement and maintain mitigation programs by identifying and developing policies, programs, and regulations that support effective risk-mitigation initiatives throughout the municipality.
- Implement programs that increase risk awareness and disaster mitigation, developing outreach programs focused on raising public awareness of hazards and their associated risks.
- Increase municipal preparedness for emergencies, response, and recovery by improving the municipality's ability to support emergency response and recovery operations. Also, maximize government coordination—among municipalities, central government, and federal agencies—during emergency situations.
- Replacement and reconstruction of bridges.

6.1.2 National Mitigation Investment Strategy

The Municipality also adopts the National Mitigation Investment Strategy and the following goals.

- **Goal 1:** Show how Mitigation Investments Reduce Risk – The whole community will build a shared understanding of mitigation investment and its value. Specifically, the whole community will understand how effective mitigation investments can protect people, homes, neighborhoods, cultural and historic resources, ecosystems and lifelines (for example, communications, energy, transportation and water). The federal government and its non-federal partners will create a shared vocabulary and common measures to communicate information about risk and find opportunities to educate, hire, train and develop a base of qualified mitigation professionals.
- **Goal 2:** Coordinate Mitigation Investments to Reduce Risk – The whole community will coordinate mitigation investments through shared risk information, reinforced strategies for risk reduction, and easier access to existing funding. Such coordination will help the whole community justify mitigation investments and choose the most cost-effective and reasonable actions.
- **Goal 3:** Make Mitigation Investment Standard Practice The whole community will factor mitigation into investment decisions, especially for buildings and infrastructure. The federal government and its non-federal partners will use and expand financial products and approaches for mitigation investment, including funding, incentives and financial risk transfer opportunities. The federal government and its non-federal partners also will make mitigation standard professional practice critical to safeguarding lifelines, services, and national safety and security.

6.2 Mitigation Strategy Selection Criteria

The following methodologies were used to select the mitigation actions:

- The Planning Committee reviewed mitigation actions from the previous Mitigation Plan.
- The Committee evaluated those actions and determined which ones were appropriate to include in the current Plan. Actions were excluded if:
 - The measure had already been implemented during the previous plan's period and was not a recurring or ongoing action.
 - The measure was no longer necessary or useful based on new information. This applies to mitigation actions linked to identified hazards, risks, and vulnerabilities.

- The Committee considered the Letters of Intent (LOIs) submitted by the municipality to COR3 in 2019 to participate in the Hazard Mitigation Grant Program. These projects were incorporated into the current Plan, ensuring no duplication of projects included in the previous Plan.
- Committee members evaluated and added new measures. These new actions were proposed based on the Committee members' professional experience and suggestions received from community members.

The mitigation strategies of the Municipality of Aguada were evaluated by the Committee using the STAPLEE methodology. This methodology was considered in the selection of the strategies included in Section 6.5. This methodology has seven evaluation criteria:

- S – Social: The proposed action must be socially acceptable.
- T – Technical: The proposed action must be technically feasible.
- A – Administrative: The community must have the capacity to implement the action (for example, determining whether the responsible agency can supervise the mitigation project).
- P – Political: Mitigation actions must be politically acceptable.
- L – Legal: The community must have the authority to implement the proposed action.
- E – Economic: Economic considerations must include the current economic base, projected growth, and opportunity costs.
- E – Environmental: The environmental impact must be considered, given statutory requirements and the public's interest in maintaining sustainable and environmentally healthy communities.

6.3 Mitigation Strategy Categorization

To further understand the chosen mitigation strategies, this LHMP classifies said strategies in five broad categories as shown below.

- Prevention – Prevention activities aim to keep hazards from creating or worsening problems. These actions are typically carried out through government programs or regulatory measures that guide land-use development and building practices. Prevention is especially effective for reducing future vulnerability in areas that have not yet been developed. Examples include:

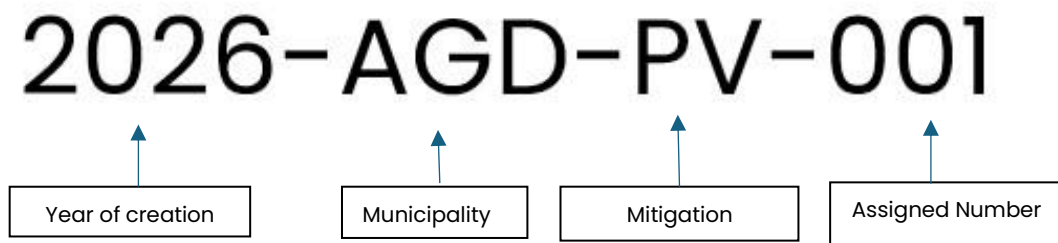
- Planning and zoning
- Building codes
- Open-space preservation
- Floodplain regulations
- Stormwater management regulations
- Maintenance of drainage systems
- Capital improvement programming
- Riverbank realignment
- Projects addressing fault zones
- Property protection – measures involve modifying existing buildings and structures so they can withstand natural hazards, or removing structures located in high-risk areas. Examples include:
 - Acquisition of properties
 - Relocation
 - Elevating structures
 - Protection of critical facilities
 - Structural retrofits (wind protection, floodproofing, seismic techniques)
 - Safe rooms, shutters, impact-resistant windows
 - Insurance policies
- Natural resource protection – activities reduce the impact of natural disasters by preserving or restoring natural areas that offer protective benefits. These areas include flood plains, wetlands, steep slopes, and sand dunes. Parks, recreational agencies, and conservation organizations commonly implement measures such as:
 - Flood protection
 - Watershed management
 - Riparian buffers
 - Forest and vegetation management (including wildfire and fuel-load control)
 - Erosion and sediment control
 - Wetland preservation and restoration
 - Habitat preservation
 - Slope stabilization
- Structural mitigation – Projects aim to reduce the impact of disasters by controlling or altering the natural flow of hazard events through engineered construction. These projects are usually designed by engineers and maintained by public works teams. Examples include:
 - Reservoirs
 - Dams, levees, and retaining walls

- Diversion, detention, and retention systems
- Channel modifications
- Stormwater drainage systems
- Installation of storm drains and related infrastructure
- Emergency Services - Although not typically classified as mitigation, emergency management measures reduce the human and property impacts of natural hazards. These actions occur immediately before, during, or after a disaster. Examples include:
 - Warning systems
 - Evacuation management and planning
 - Emergency response drills and training
 - Flood-fighting measures
 - Installation of shutters
- Public awareness and outreach - Efforts to help inform residents, elected officials, business owners, homebuyers, and visitors about hazard-prone areas and mitigation techniques they can use to protect themselves and their property. Examples include:
 - Outreach projects
 - Demonstration events and guest presentations
 - Hazard information materials
 - Property-specific risk information
 - Library materials
 - Educational programs for children
 - Exposure to risk-related information

6.4 Mitigation Strategies (C4-a, C4-b, C5-a, C5-b, E2.b)

To improve tracking and updating, each mitigation strategy has been given a unique identification number. The following figure shows the meaning of the nomenclature.

Figure 39. Unique Id Nomenclature



Each identified mitigation strategy shall include:

- Assigned category,
- Hazard(s) Mitigated
- Priority
- Responsible entity
- Founding source
- Estimated cost (when available)
- Qualitative Benefit
- Time Horizon
- Status
- Location in 2018 (if applicable)

Table 55. Mitigation Strategies – Local Planning and Regulation

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-LP-001	P -1	Avoid development in areas of high risk of coastal flooding to mitigate future losses through land use regulation and planning, including the revision of the Land Use Plan, to incorporate the results of the Risk Mitigation Plan.	Flooding	High	Safety & Security	Leader: Planning Office Support: Mayor's Office	Municipal, State (Planning Board)	Short Term	Current Status: On Going– The strategy was completed through the review and approval of the Territorial Plan by the Planning Board in December 2024. The Plan will continue to be reviewed and updated, as needed, to ensure consistency with current hazard mitigation goals, land use policies, and flood risk information. Although the municipality does not have authority to issue construction permits, it supports flood risk reduction through land use recommendations and planning policies that discourage development in high-risk coastal flood areas. For projects proposed within flood-prone areas, the municipality may request an elevation certificate prepared by a qualified professional to demonstrate compliance with applicable floodplain management requirements. This strategy reduces future flood risk by guiding development away from high-risk coastal areas, strengthening land use planning, supporting safer development practices, and enhancing the community's long-term resilience to flooding.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-LP-002	P -2	Develop a new evacuation route along State Highway 441 towards the municipal road from Barrio Carrizal, to Barrio Tablonal in case of flooding. This new strategy is suggested so that the inhabitants of the Carrizal neighborhood can leave their homes in case of a flood and avoid loss of life.	Flooding	High	N/A	N/A	N/A	N/A	Current Status: Withdrawn – Implementation of this strategy is not feasible as originally proposed because the identified project segment is under federal jurisdiction and contains federal communications infrastructure. The municipality does not have the authority to implement the proposed action at that location. At this time, no practical alternative alignment or location has been identified by the municipality. Therefore, the strategy has been suppressed from this LHMP and will be removed during the next LHMP update.
2026-AGD-LP-003	P -3	The municipality and its dependencies will actively participate in the effort to implement land use controls to prohibit the development of illegal structures in flood-prone areas pursuant to the Special Flood Hazard Areas Regulation, better known as Planning Regulation #13, as amended and Joint Regulation (ZR)	Flooding	High	Safety & Security	Leader: Planning Office Support: Mayor's Office	Municipal, State, or Federal	Short Term	Current Status: Ongoing Implementation – At the moment, no cases requesting new construction in flood-prone areas have been received. The Municipality, within its authority, does not endorse projects in this zone. This strategy will prevent unsafe development in flood-prone areas, reduce potential damage to property and infrastructure, enhance regulatory compliance, and protect public safety by minimizing exposure to flood hazards.
2026-AGD-LP-004	New	Develop response plans for extreme heat events	Extreme Heat	High	Health and Medicine	Leader: Emergency Management (OMME) Support: Public Works	Municipal	Short Term	Current Status: New – This strategy strengthens response capacity to extreme heat events, improves coordination among responsible entities, and helps reduce health risks to the population during periods of high temperatures.
2026-AGD-LP-005	New	Develop a strategic reforestation plan with the purpose of providing shade and strategic cooling areas in the urban areas of the municipality.	Extreme Heat	High	Food, Hydration and Shelter	Leader: Emergency Management (OMME) Support: Public Works	Municipal	Medium Term	Current Status: New – This strategy will help reduce temperatures in urban areas, increase tree canopy coverage, and promote shaded spaces that improve community well-being and resilience to extreme heat.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-LP-006	New	Reinforce, through municipal ordinances, the imposition of fines for the illegal disposal of materials such as garbage, debris, landfill and other materials that tend to reduce the natural flow and quality of water. The illegal practice of disposing of these materials near bodies of water, protected natural resource areas, sewers and drains, to name a few, increases or causes severe flooding in urban areas.	Flooding	High	Food, Hydration and Shelter	Leader: Emergency Management (OMME) Support: Public Works	Municipal	Short Term	Current Status: New – This strategy will reduce flood impacts by preventing the obstruction of drainage systems and natural waterways, improving water flow and water quality. In addition, it will help protect water sources, infrastructure, and properties, strengthening community resilience to heavy rainfall and flooding events.
2026-AGD-LP-007	New	Maintain a municipal inventory of wildfire events in order to identify vulnerable areas	Wildfire	High	Safety & Security	Leader: Emergency Management (OMME) Support: Public Works	Municipal	Short Term	Current Status: New – This strategy enables the identification of areas at higher risk of wildfires, facilitating the planning of preventive measures, the efficient allocation of resources, and the development of mitigation actions that reduce damage to the population, infrastructure, and natural resources.
2026-AGD-LP-008	New	Access to drinking water in municipal activities. Programs to provide access to drinking water in a controlled manner during extreme heat events in large municipal activities such as festivals, patron saint festivities, Christmas lighting or any other, in order to prevent dehydration and reduce health risks associated with extreme heat. This may be filtered water fountains installed in specific activities.	Extreme Heat	High	Food, Hydration and Shelter	Leader: Emergency Management (OMME) Support: Public Works	Municipal	Short Term	Current Status: New – This strategy reduces the risks of dehydration and heat-related illnesses, protects vulnerable populations, and strengthens community resilience to the increasing occurrence of extreme heat events.

Table 56. Mitigation Strategies – Property Protection

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-PP-001	PP –1	Improve flood vulnerability data and maps in the Mamey neighborhood, Juan XXIII Sector PR-4417 (14 households); floods in the Cruces neighborhood, López Sector (below) PR-414; the Guanábano neighborhood, Parcelas Luyando; the Guanábano and Asomante neighborhoods, Coloso Community and in the Espinar neighborhood, PR-4439 (highway). This strategy was taken from the previous plan and tempered and updated so that it reads as follows: We will work with the Central Government and FEMA to update the Municipality's flood maps to make flood risk data clearer, prevent construction in areas susceptible to flooding for residents of the Municipality's 18 neighborhoods.	Flooding	High	Safety & Security	Leader: Office of Management and Emergency (OMME) Support: Planning Office	Municipal	Medium Term	Current Status: Completed – Currently, in the updated maps, the Community of Barrio Mamey is located in flood zone A. Barrio Cruces is located in zones A and AE. Barrio Guanabano, sector Coloso, is located in zones A and AE. Barrio Asomante, road 115, is located in zone AE. Strategy suppressed in this LHMP. This action has been carried out by a central government agency or authority.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-PP-002	PP -2	Begin an inventory of all critical and private structures across all 18 neighborhoods in the Municipality using the GIS system. To efficiently identify these structures on Municipal maps and thus be able to identify and accurately estimate the cost of the same in order to mitigate future losses in the face of flood danger. This strategy was taken from the previous plan and tempered and updated so that it reads as follows: Create a timetable to initiate tabulation of all critical and private structures across the 18 neighborhoods. For this, a geospatial information system (GIS) will be used to identify latitudes, longitudes creating a database of maps to be able to identify and accurately estimate the cost of the identified structures in order to mitigate future losses in the face of flood danger.	Flooding	High	Communication	Leader: Office of Management and Emergency (OMME) Support: Planning Office	State or Federal	Medium Term	Current Status: Funding The Municipality currently maintains an inventory of municipal and state critical structures; however, it does not yet have a Geographic Information System (GIS) program or dedicated technical personnel. Efforts are underway to identify and secure the necessary funding and staffing resources to implement this initiative, including the acquisition of GIS capabilities and the hiring or training of qualified personnel. This strategy will improve flood risk assessment by providing accurate geospatial data on critical and private structures, enabling better planning, cost estimation, and decision-making while reducing future flood-related damages and economic losses.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-PP-003	PP -3	Mitigate the risk of landslides by creating and enforcing regulations that restrict the construction of new projects in landslide-susceptible areas and implementing soil-stabilizing vegetation and/or adequate barriers to protect the following state and municipal highways and private structures as described below. The roads that need to mitigate the most damage are the following: State roads (417, 411,419,414,447,441). The neighborhoods and municipal roads that are to be served are the following: Barrio Jagüey 411 Int., Barrio Naranjo #2, 419 and 416 Int., Barrio Cerro Gordo 417 and #2 Int., Barrio Atalaya carr.419, 411 Int., 4411 Int., Barrio Atalaya 419, 411 Int., 4411 Int. Barrio Guanábano 417 Int., Barrio Mamey 4417 Int., Cruces 414 Int., Barrio Espinal area of the Coast, Barrio Piedras Blancas 416 Int., Barrio Las Marías Carr 417 Int., among others. For private properties, it includes the Atalaya, Marías, Laguna, Naranjo and Cerro Gordo neighborhoods.	Landslide, Earthquake	#CONNECT!	Transportation	Leader: Public Works Support: Planning Office	Municipal, Federal (USGS, USDA, DRNA, DTOP)	Medium Term	Current Status: Ongoing Implementation – Through this strategy, several stabilizing walls have been constructed in different neighborhoods such as Cerro Gordo, Naranjo, Piedras Blancas, Jagüey, Guanábano, Cruces, Atalaya, and Lagunas, to repair road failures. This strategy will reduce landslide risk and roadway failures, improve the stability of slopes and critical infrastructure, enhance public safety, ensure safer transportation routes, and increase the resilience of vulnerable communities and structures.
2026-AGD-PP-004	PP -4	Installation of storm shutters, water cisterns and electric and/or solar generators in the critical facilities of the municipal government in order to continue providing basic and essential services to citizens.	Tropical Cyclone/Extreme Winds	High	Food, Hydration and Shelter	Leader: Public Works Support: Planning Office	Municipal, Federal (FEMA)	Short Term	Current Status: In Implementation – Cisterns have been installed in various critical municipal facilities. A project for the installation of storm shutters was approved with 404 funds. At present, the bidding process for the acquisition of storm shutters has been completed. This measure will help protect the interior of municipal buildings from the impacts of natural hazards and safeguard office documentation. It will also support the continued provision of essential services during events such as droughts or power outages.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-PP-005	PP -5	Reconstruction and improvements to the bridge located in Barrio Lagunas, highway 416, Km 5.2 Int. Sector JB	Landslide, Flood	High	Transportation	Leader: Public Works Support: Planning Office	State, Federal (FEMA)	Medium Term	Current Status: In Design – Although the municipality submitted letters of intent to obtain funding from the 404 HMGP program, but they were not approved. FEMA funds, were obtained to improve the “head walls.” Design work will begin soon. This strategy will reduce flood and landslide risks at a critical crossing point, improve structural integrity and drainage capacity, enhance public safety, ensure reliable transportation access, and strengthen the resilience of nearby communities and infrastructure.
2026-AGD-PP-006	PP -6	Reconstruction and improvements to the bridge in Barrio Naranjo, highway 2 Km 138.7 Int. (Lands of Eligio)	Landslide, Flood	High	Transportation	Leader: Planning Office Support: Public Works	State, Federal (FEMA)	Short Term	Current Status: In-progress – This project has been awarded and is currently under construction. Municipality will continue to follow-up and make necessary coordination's in order to complete construction. This project benefits the community as it ensures access to their residences and improves the community's infrastructure.
2026-AGD-PP-007	PP -7	Reconstruction and elevation improvements of the bridge in Barrio Cerro Gordo, highway #2 Km 136 Int. Riverside Sector.	Landslide, Flood	High	Transportation	Leader: Planning Office Support: Office of Federal Programs	State, Federal (FEMA)	Long Term	Current Status: Funding – It has not been carried out due to the need to identify a funding source. This project benefits the community as it ensures access to their residences and improves the community's infrastructure.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-PP-008	PP -8	Reconstruction and improvements to the bridge in Barrio Las Marías, highway 417 Km 7.3 Sector Hoyo Frio Int.	Landslide, Flood	High	Transportation	Leader: Planning Office Support: Public Works	State, Federal (FEMA)	Short Term	Current Status: Funding – The project was submitted to FEMA as part of the damages caused by Hurricane Maria. The project was recently obligated, and a bidding process for design will be carried out. This project benefits the community as it ensures access to their residences and improves the community's infrastructure.
2026-AGD-PP-009	PP -9	Reconstruction and improvements to the bridge in Barrio Naranjo Militar, highway #2 Km 135.1 Sector El Dominicano	Landslide, Flood	High	Transportation	Leader: Planning Office Support: Public Works	State, Federal (FEMA)	Medium Term	Current Status: In Design –The project was submitted to FEMA as part of the damages caused by Hurricane Maria. The project was recently obligated, and a bidding process for design will be carried out. This project benefits the community as it ensures access to their residences and improves the community's infrastructure.
2026-AGD-PP-010	PP - 10	Reconstruction and improvements to the elevation of the bridge in Barrio Guanábano, highway 417 Int. Km 3.4 Sector Luyando (Puente el Camello)	Landslide, Flood	High	Transportation	Leader: Planning Office Support: Public Works	State, Federal (FEMA)	Short Term	Current Status: In Implementation – This strategy is currently in the bidding process. It was requested through the 404 Mitigation program. Approval was received from FEMA, and the Municipality carried out a bidding process for the design. This project benefits the community as it ensures access to their residences and improves the community's infrastructure.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-PP-011	PP -11	Reconstruction and improvements to the elevation of the bridge in Barrio Mamey, highway 4417 Km 1.1, Hilda Rosa Sector	Landslide, Flood	High	Transportation	Leader: Planning Office Support: DTOP	State, Federal (FEMA)	Medium Term	Current Status: Funding - This project was submitted under the 404 HMGP program, but it was not approved since it is on a state road and the Municipality does not have jurisdiction over them. This strategy will reduce flood and landslide risks at a critical bridge location, improve road elevation and structural resilience, enhance public safety, ensure reliable access for residents, and strengthen the overall resilience of the surrounding community.

Table 57. Mitigation Strategies – Structural Improvement

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-SI-001	PE -1	Construction of Boulevard Sports Complex Sector Casualidad del Bo. Guayabo de Aguada; Improvements to existing bridge including elevation of structure.	Flooding	N/A	N/A	N/A	N/A	N/A	Current Status: Completed – Completed on July 31, 2013. It shall be removed in the next LHMP revision.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-SI-002	PE -2	Improvements and Land Elevation at the Senior Multi-Activity Center (CAMPEA), Bo. Espinal. The original building is located in a flood-prone area in the Bo. Espinal. The project includes elevation of the land and improvements to the original structure (before it was made of wood and did not resist hurricane winds; now in concrete).	Tropical Cyclone/Extreme Winds, Flooding	N/A	N/A	N/A	N/A	N/A	Current Status: Completed – Completed in 2023 It shall be removed in the next LHMP revision.
2026-AGD-SI-003	PE -3	Conduct a study to identify mitigation measures in tsunami-prone areas, including the alternative of building structures for vertical evacuation.	Tsunami	High	Safety & Security	Leader: Planning Office Support: Office of Federal Programs	Municipal	Medium Term	Current Status: Funding – A project was submitted on the State’s BRICs platform, but with the new Federal government policies the funding was closed. It has not been carried out due to the need to identify a funding source This strategy will improve understanding of tsunami risk in vulnerable areas, support informed decision-making for future mitigation investments, enhance community preparedness, and identify effective evacuation solutions such as vertical evacuation structures to reduce potential loss of life.
2026-AGD-SI-004	PE -4	Acquisition of land for the expropriation of two (2) commercial structures that are flooded and create open spaces in what will be La Puerta del Descubrimiento.	Tsunami, Flood	N/A	N/A	N/A	N/A	N/A	Current Status: Withdrawn – Suppressed from this LHMP as it lacks specificity. It will be eliminated from the next LHMP revision. This strategy was not advanced as the specific structures could not be identified.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-SI-005	PE -5	"Coastal Road Collapsing Mitigation"; This includes road repair and coastal erosion at Pico de Piedra (Camino de la Playa Bo. Guaniquilla). This strategy is new and will be implemented to prevent the further erosion of part of the coasts of Pico de Piedra.	Coastal Modification	Medium	Transportation	Leader: Public Works Support: Planning Office	Municipal, State, Federal (FEMA)	Short Term	Current Status: On Going Implementation A bidding process was carried out for repair, but no proposals were received from contractors. A bidding process will be conducted to design the repair method. This strategy will reduce coastal erosion and roadway collapse risks, protect critical transportation infrastructure, enhance public safety for residents and visitors, preserves reliable access to coastal areas, and strengthen the resilience of the coastline against recurring coastal hazards.
2026-AGD-SI-006	PE -6	Construction of sidewalks and new gutters on different municipal roads to prevent flooding on various roads in the different neighborhoods of Aguada.	Flooding	High	Water Systems	Leader: Public Works Support: Office of Federal Programs	Federal (FEMA), State	Short Term	Current Status: Ongoing Implementation – Construction of drainage ditches has been carried out in Barrio Cerro Gordo, Barrio Naranjo, Barrio Mamey, Barrio Pueblo (new South Bypass). 261,045.17 The construction of sidewalks and drainage ditches is planned for Camino La Playa. This strategy will reduce flood risk along municipal roadways, improve stormwater management and drainage capacity, enhance pedestrian safety through the construction of sidewalks, protect critical infrastructure, and ensure more reliable transportation access during heavy rainfall events.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-SI-007	PE -7	Channeling of the Culebrinas River and construction of dikes in Barrio Espinal de Aguada.	Flooding	N/A	N/A	N/A	N/A	N/A	Current Status: Withdrawn – Suppressed in this LHMP as it is beyond the municipality’s scope of responsibility and delegated powers. The project has remained in the design phase for several years, and despite municipal efforts to obtain updates, no information has been provided. It will be eliminated from the next LHMP revision.
2026-AGD-SI-008	PE -8	"Box Culvert" on the Aguada South Detour Highway (Section or area in front of "Grand Store")	Flooding	High	Water Systems	Leader: Planning Office Support: Mayor's Office	Federal (City Revitalization)	Short Term	Current Status: Completed – Currently benefiting approximately 13,836 vehicles that travel daily through the area. The implemented improvements continue to reduce flood risk in this high-traffic corridor, enhance stormwater conveyance capacity, prevent roadway overtopping, protect critical transportation infrastructure, and ensure safe and reliable access for daily users. As this project has been completed, it shall be removed in the next LHMP revision.
2026-AGD-SI-009	New	Construction and labeling of evacuation routes and structures to higher areas.		High	Transportation	Leader: Emergency Management (OMME) Support: Public Works	Municipal, State, Federal	Medium Term	Current Status: On Going Implementation – Through the Emergency Management Office together with the Zone, (E) signage toward evacuation points is being worked on. Tsunami Ready exercises are conducted with the communities. This strategy will improve public safety by clearly identifying evacuation routes and shelters, enhancing community preparedness, reducing response time during emergencies, and minimizing risks to life and property during tsunamis and flood events.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-SI-010	New	Designate and prepare municipal facilities throughout the municipality to serve as cooling centers during heat waves.	Extreme Heat	High	Safety & Security	Leader: Emergency Management (OMME) Support: Office of Federal Programs	Municipal, State	Medium Term	Current Status: New – This strategy reduces health risks during heat waves by providing safe, temperature-controlled spaces for vulnerable populations. This strategy improves public safety, prevents heat-related illnesses, and strengthens community resilience during extreme heat events.
2026-AGD-SI-011	New	Refurbish or construct transit stops to provide shade for pedestrians and transit users.	Extreme Heat	High	Food, Hydration and Shelter	Leader: Emergency Management (OMME) Support: Public Works	Municipal, State, Federal	Medium Term	Current Status: New – This strategy improves comfort and safety for pedestrians and transit users by reducing heat exposure. It encourages public transportation use, protects vulnerable populations, and enhances urban resilience to rising temperatures.
2026-AGD-SI-012	New	Design and install fixed water supply points in strategic high-risk areas (tanks, rural hydrants, cisterns or artificial ponds) to facilitate the rapid response of brigades against forest fires, reducing operating times and increasing suppression capacity.	Forest Fire	High	Safety, Water Systems	Leader: Public Works Support: Emergency Management (OMME)	Municipal	Short Term	Current Status: New – Strategy identified during the plan update to strengthen wildfire response capacity. Priority locations and possible sources of financing for its implementation will be evaluated.
2026-AGD-SI-013	New	Construction of runoff management systems such as bioswales or infiltration ditches, rain gardens and natural retention areas, designed to capture surface runoff and allow its infiltration into the soil, favoring the recharge of aquifers while at the same time reducing surface runoff that when accumulated can cause floods and landslides.	Landslides, Floods, Drought and Extreme Heat	High	Water Systems	Leader: Public Works Support: Recovery	Municipal, State or Federal	Short Term	Current Status: New – Incorporated strategy to promote sustainable runoff management and risk reduction associated with floods, landslides, drought and extreme heat. It requires evaluation of potential areas for implementation.
2026-AGD-SI-014	New	Implementation of slope stabilization systems using retaining walls, soil nailing and/or geosynthetic meshes to reduce the risk of landslides on municipal roads exposed to high slopes and heavy rainfall	Landslides	High	Transportation	Leader: Public Works Support: Recovery	Municipal, State or Federal	Short Term	Current Status: New – Municipal roads with greater susceptibility to landslides will be identified to evaluate slope stabilization alternatives and priorities for intervention.

Table 58. Mitigation Strategies: Natural Resources Protection

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026 –AGD –NR –001	PRN–1	Mitigate the risk of flooding in the coastal zone by creating and enforcing regulations that restrict the construction of new projects in the area and ensure that conservation buffer zones are used during flooding.	Flooding	High	Safety & Security	Leader: Emergency Management Office (OMME) Support: Planning Office	Municipal, State and Federal	Long Term	Current Status: Ongoing Implementation – The Municipality is not endorsing new projects in coastal areas susceptible to flooding. This strategy will reduce flood risk in coastal areas by limiting development in high-risk zones, preserving natural buffers, protecting infrastructure, and enhancing long-term community resilience.
2027 –AGD –NR –001	New	Reduce impact energy by dissipating hydraulic energy through natural barriers in Carrizales: –Dune restoration –Planting of fixing vegetation –Establishment of coastal forests (button mangroves, ucar, Almacigo, etc.)	Tsunami	High	Safety & Security	Leader: Emergency Management Office (OMME) Support: Public Works	Municipal, State and Federal	Long Term	Current Status: Ongoing Implementation –The Municipality has already carried out coastal vegetation planting campaigns in Barrio Espinal. This strategy reduces coastal erosion and shoreline degradation while dissipating wave and tsunami energy, protecting infrastructure and communities. It also restores natural habitats, enhances biodiversity, strengthens climate resilience, and supports long-term environmental sustainability and local economic stability.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2028 –AGD –NR –001	New	Protect natural bodies of water (streams, lagoons, ponds) and their riparian areas, in order to contribute to the thermal regulation of the environment through evaporation and natural cooling processes.	Drought, Extreme Heat, Wildfire	High	Water Systems	Leader: Administration Support: Public Works	Municipal, State and Federal	Medium Term	Current Status: New – This strategy improves environmental resilience by restoring natural water bodies and their riparian zones, which help regulate local temperatures through natural cooling processes. In addition, it improves water quality, supports ecosystems, and reduces the impacts of heat, drought, and flooding on surrounding communities.
2029 –AGD –NR –002	New	Implement vegetation management programs in high-risk areas through controlled fuel reduction (dry material, grass, dense shrubs) and the establishment of firebreaks around communities, critical infrastructure, and access corridors, with the goal of reducing the likelihood of ignition and limiting the spread of wildfires. These actions must be carried out in accordance with technical plans that define the frequency, handling methods and proper disposal of the removed material, avoiding inappropriate practices such as the uncontrolled accumulation or burning of plant waste.	Forest Fire	High	Safety & Security	Leader: Public Works Support: Emergency Management (OMME)	Municipal, State and Federal	Medium Term	Current Status: New – This strategy reduces the risk of wildfires by decreasing the buildup of vegetative fuels and limiting the spread of fire near communities and critical infrastructure.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2030 –AGD –NR –003	New	Restoration of complete coastal wetland systems (mangrove-marsh-beach transition) to increase sediment retention, buffer wave energy or hydraulic impact, allow natural migration of ecosystems in the face of sea level rise and also to function as a buffer zone to capture and filter pollutants transported by the flooding of the event.	Storm Surge, Flood, Tropical Cyclone/Extreme Winds, Coastal Modification	High	Safety, Security, Hazardous Materials	Leader: Public Works Support: Emergency Management (OMME)	Municipal, State and Federal	Short Term	Current Status: New – This strategy strengthens coastal resilience by reducing the impact of waves and flooding, improving sediment retention, and supporting natural protection from sea level rise and pollution associated with coastal events.
2031 –AGD –NR –004	New	Implementation of "living shoreline" solutions using a combination of native coastal vegetation, preferably salinity-tolerant species (halophytes), as well as oyster reefs, anchored logs and biodegradable elements, strategically designed and installed to stabilize the coastline, reduce erosion and maintain natural ecological processes in the face of waves and sea level rise. Species tolerant to adverse conditions, such as vetiver (<i>Chrysopogon zizanioides</i>), which have demonstrated resistance to temporary wave or flood events, may be used in transition zones.	Long-term Coastal Modification, Tsunami	High	Safety & Security	Leader: Public Works Support: Emergency Management (OMME)	Municipal, State and Federal	Short Term	Current status: New – This strategy strengthens coastal resilience by reducing erosion, conserving coastal ecosystems, and increasing natural protection from waves and sea level rise.
2032 –AGD –NR –005	New	Protect ecological corridors and open spaces that facilitate natural ventilation and airflow in urban areas, avoiding their fragmentation by development, in order to mitigate heat accumulation.	Extreme Heat	High	Safety, Security, Food, Hydration and Shelter	Leader: Management Support: Public Works, Recovery, Municipal Police	Municipal	Short Term	Current Status: New – The City will promote coordination with state and federal agencies to identify and protect ecological corridors and open spaces that favor natural ventilation and contribute to reducing heat accumulation in urban areas.
2033 –AGD –NR –006	New	Create shade corridors, strategic reforestation projects with drought-resistant and native species, rain gardens, infiltrating soils, and vegetative firebreak strips to reduce urban temperatures, increase moisture retention, and decrease fire spread.	Drought, Extreme heat, Wildfire	High	Safety, Security, Food, Hydration and Shelter	Leader: Management Support: Public Works, Recovery	Municipal, State and Federal	Medium Term	Current Status: New – This strategy encourages reforestation, the creation of rain gardens, and fire strips which will provide less heat, humidity and fewer fires.

Table 59. Mitigation Strategies – Emergency Services

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-ES-001	New	Install solar panel systems in critical facilities to ensure continuity of operations during power outages and emergency events in essential infrastructure, such as the Ismael "Chavalillo" Coliseum, Guillermo Hernandez Stadium, City Hall, the Office of Federal Programs, the Municipal Office for Emergency Management (OMME) and the Municipal Police.	Tropical Cyclone/Extreme Winds and Earthquake	High	Energy	Leader: Office of Federal Programs Support: Mayor's Office	Federal (HMGP, CDBG, MIT, NMEAD), State	Long Term	Current Status: New – This strategy ensures that storage and distribution centers remain energized and operational during emergency events, supporting continuity of operations, maintaining a reliable food supply, enhancing energy resilience through backup and renewable power systems, reducing service disruptions during hazardous events, and strengthening the municipality's capacity to respond to and recover from emergencies.
2026-AGD-ES-002	New	Improve or develop integrated communication and early warning systems capable of issuing warnings through multiple channels, including alarms, visual signals, and digital platforms, to inform the community about natural hazards, expected risks, protective measures, evacuation routes, shelter locations, road conditions, and other critical information before, during, and after an event, supporting a timely response and a more effective recovery.	All	Medium	Communication	Leader: Emergency Management (OMME) Support: Planning Office	Municipal, State and Federal	Medium Term	Current Status: New – This strategy improves public safety by ensuring timely and reliable communication before, during, and after emergencies. By delivering clear warnings and guidance through multiple channels, it enables faster decision-making, supports evacuation and protective actions, and reduces risks to life and property from hazards such as extreme heat, hurricanes, earthquakes, floods, Tsunami, droughts, landslides, and wildfires.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-ES-003	PEM-1	Acquisition of electricity generators for critical facilities of the municipality.	All	Medium	Energy	Leader: Office of Federal Programs Support: Mayor's Office	Federal (FEMA), Munciipal	Medium Term	Current Status: On Going Implementation – Municipal Police and Emergency Management Office acquired a generator to support emergency operations. The continued acquisition of generators for critical municipal buildings will enhance resilience and emergency preparedness through reliable backup power systems, support uninterrupted delivery of essential services, reduce downtime during hazard events, and strengthen the municipality's capacity to respond to and recover from disasters.

Table 60. Mitigation Strategies – Education and Awareness

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-EA-001	PEM -1	Acquisition of electricity generators for critical facilities of the municipality.	All	N/A	N/A	N/A	N/A	N/A	Current Status: Reclassified – It will be removed from this table in the next LHMP review and will be assigned to Emergency Services Table with the new identification 2026-AGD-ES-003.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-EA-002	EAP-1	Develop an Education Program on the different hazards assessed in the HMP (earthquakes, tsunami, high winds, fire, flooding in rivers and coasts, rain-induced landslides, and earthquakes), including educational material and information on structural and non-structural improvements aimed at businesses and residents. If applicable, evacuation information will be provided during events. The educational program will include, among other topics, information related to NFIP flood insurance and resident benefits.	All	Medium	Safety & Security	Leader: Emergency Management (OMME) Support: Planning Office	Municipal or external funds	Medium Term	Current Status: Ongoing Implementation – OMME continues carrying out activities in schools and communities, providing workshops and distributing brochures with information on various risks. This strategy will increase public awareness and understanding of natural hazards, promote risk-informed decision-making among residents and businesses, support the adoption of structural and non-structural mitigation measures, enhance community preparedness and response capabilities, and reduce potential loss of life and property through improved education and outreach.
2026-AGD-EA-003	PEA-2	Provide structural and non-structural improvement information so that property owners can make improvements to existing structures to reduce damage caused by seismic events and other natural hazards by establishing a library of technical documents related to structural and non-structural improvement options, as well as the revised HMP, federal laws, state laws, ordinances, building codes, land use plans, among others.	All	Medium	Safety & Security	Leader: Emergency Management (OMME) Support: Mayor's Office	Municipal	Medium Term	Current Status: Ongoing Implementation – An educational program was conducted in schools to guide residents on structural improvements and reconstruction aligned with FEMA manuals and standards. This strategy has increased public awareness and understanding of natural hazards, promote risk-informed decision-making among residents and businesses, support the adoption of structural and non-structural mitigation measures, enhance community preparedness and response capabilities, and reduce potential loss of life and property through improved education and outreach.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-EA-004	PEA-3	Improve flood risk assessment and increase risk awareness by reviewing and updating Flood Insurance Rate Maps (FIRMs) maps that reflect current flood areas in the municipality.	Flooding	Medium	Safety & Security	Leader: Emergency Management (OMME) Support: Mayor's Office	Federal (FEMA)	Medium Term	Current Status: Ongoing Implementation – An educational initiative was implemented in schools to inform residents about flood risks and preparedness measures, including understanding updated flood maps and complying with FEMA flood management guidelines. This strategy will provide the following qualitative benefits. Through this update, there is a better understanding of the municipality's flood-prone areas.
2026-AGD-EA-005	PEA-4	Develop an awareness and education program, through workshops, talks and/or publications aimed at merchants, stakeholders and the general public about the importance of water conservation and alternatives for its storage and protection.	Drought	Medium	Water Systems	Leader: Emergency Management (OMME) Support: Mayor's Office	Municipal, State, Federal	Short Term	Current Status: Ongoing Implementation – OMME continues to carry out numerous activities, workshops, and distributes informational flyers. This strategy raises awareness of water conservation, encourages efficient water use and storage, and strengthens community resilience to drought conditions.
2026-AGD-EA-006	PEA-5	Inform the public, through workshops, talks and/or publications, about the importance and benefits of participating in the National Flood Insurance Program (NFIP)	Flooding	Medium	Safety & Security	Leader: Emergency Management (OMME) Support: Mayor's Office	Municipal, State, Federal	Short Term	Current Status: Ongoing Implementation – OMME continues to carry out numerous activities, workshops, and distributes informational flyers. This strategy increases awareness of flood insurance and helps reduce financial losses from flooding while improving community resilience and preparedness.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-EA-007	PEA-6	Educate merchants, stakeholders and the general public, through workshops, talks and/or publications and external resources on the importance of avoiding fires due to spontaneous combustion of pastures in the municipality.	Forest Fire	High	Safety & Security	Leader: Emergency Management (OMME) Support: Mayor's Office	Municipal, State, Federal	Short Term	Current Status: Ongoing Implementation – OMME continues to carry out numerous activities, workshops, and distributes informational flyers. This strategy increases awareness of fire prevention practices, reduces the risk of vegetation fires caused by spontaneous combustion, and promotes safer land management. It also enhances community preparedness, protects natural resources and property, and strengthens overall environmental and public safety resilience.
2026-AGD-EA-008	New	Develop, in collaboration with central agencies and non-profit organizations, information campaigns (educational materials, talks, announcements) on the risks of extreme heat and the preventive measures applicable at home and in outdoor spaces.	Extreme Heat	High	Safety & Security	Leader: Emergency Management (OMME) Support: Mayor's Office	Municipal	Medium Term	Current Status: New – This strategy will reduce unnecessary exposure to extreme heat events, minimize all costs related to medical emergencies associated with extreme heat, and promote sustainable and resilient practices during extreme heat events.
2026-AGD-EA-009	New	Develop an educational program for residents and contractors on safe slope management practices, including prohibiting cuts without technical design, proper runoff management, and the importance of maintaining vegetation cover. The program should emphasize the negative impacts of indiscriminate herbicide use and vegetation removal, which can increase erosion and lead to landslides.	Extreme heat, landslides, tropical cyclone/extreme winds	High	Safety & Security	Leader: Emergency Management (OMME) Support: Mayor's Office	Municipal	Short Term	Current Status: New – This strategy will promote proper slope management practices, reduce soil erosion and landslide risk, and encourage the protection of vegetation cover as a mitigation measure.

2026 ID	2020 ID	Description	Danger	Priority	Lifeline	Municipal Office in Charge	Possible Sources of Funds	Implementation Term	Status
2026-AGD-EA-010	New	Conduct community outreach sessions on the installation and management of rainwater harvesting and storage systems (e.g., cisterns), targeting communities, as a measure to increase resilience to drought events or situations where water service may be affected.	Drought, Tropical Cyclone/Extreme Winds, Earthquakes	High	Water Systems	Leader: Emergency Management (OMME) Support: Mayor's Office	Municipal	Medium Term	Current Status: New - Community outreach on rainwater collection and storage systems, such as cisterns, helps increase water availability during droughts and service interruptions. This strategy reduces reliance on municipal systems, promotes sustainable practices, and improves household and community resilience during events like hurricanes and earthquakes.
2026-AGD-EA-011	New	Implement community-based hands-on workshop programs focused on urban agriculture, basic food management, and small-scale production, supported by educational gardens, in order to strengthen applied knowledge, food self-sufficiency, and community resilience. This strategy contributes to improving food security, reducing reliance on external supply chains, and increasing responsiveness to disruptions, such as those experienced during pandemics, when access to food may be limited.	Pandemic/Epidemic	High	Food, Hydration and Shelter	Leader: Emergency Management (OMME) and Planning Support: Mayor's Office	Municipal	Medium Term	Current Status: New - Community workshops on urban agriculture and food handling strengthen food security by reducing dependence on external supply chains. They build practical skills, promote self-sufficiency, and enhance the community's ability to respond to disruptions, particularly during emergencies such as pandemics.

6.5 Participation in the NFIP

Covered under the PRPB, the Municipality maintains continuous participation in the National Flood Insurance Program (NFIP) and remains committed to meeting all program requirements to reduce flood risk and protect life and property. Ongoing participation in the NFIP enables residents and businesses to access federally backed flood insurance while promoting sound floodplain management practices. The PRPB, on the municipality's behalf, enforces floodplain management regulations consistent with FEMA requirements, including the adoption and use of Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FIS) for development decisions. Local permitting, inspection, and enforcement activities help ensure that new construction and substantial improvements in Special Flood Hazard Areas comply with applicable elevation and floodproofing standards. The Municipality also supports public awareness and education activities related to flood risk, insurance requirements, and mitigation measures. Continued compliance with the NFIP strengthens eligibility for federal hazard mitigation funding and supports the long-term reduction of flood-related damages.

7. Plan Maintenance

This chapter describes the procedures and actions necessary to ensure that the Plan is effectively implemented, regularly reviewed, and maintained in alignment with the established mitigation goals and objectives. In some instances, Plan updates may require adjustments to proposed mitigation actions to reflect changes in on-site conditions that could either increase or reduce the level of risk affecting certain areas.

In accordance with federal requirements, the Local Hazard Mitigation Plan (LHMP) review process must include the following elements:

- A description of the methods and schedule for monitoring, evaluating, and updating the Mitigation Plan within a five-year period.
- A process for integrating the Mitigation Plan's requirements into other applicable local planning mechanisms, such as comprehensive plans or capital improvement plans.
- A description of how the community will continue to participate in the Plan's review and maintenance process.

7.1 Point of Contact

The designated point of contact is responsible for the monitoring, revision, and update of the Municipality of Aguada. LHMP is as follows:

Table 61. Point of Contact Information

Name:	Wesley Vega
Position:	Director
Office:	Planning Office
Telephone:	(787) 868-6155
Email:	wvega@aguada.gov.pr

7.2 Continuous Public Participation (D1-a)

The Municipality of Aguada is committed to ensuring ongoing public participation by

implementing the following engagement methods:

- Public education and awareness initiatives
- Surveys
- Community workshops and meetings held throughout the municipality

Consistent with this commitment, public participation and community education are integral components of several mitigation strategies included in this Plan. Residents are encouraged to submit comments and participate in LHMP updates at any time, including requesting copies of the Plan during its development, monitoring, and maintenance phases.

Each time a progress report is completed, it will be made available for public review. Plan progress will also be discussed periodically during public meetings and shared through social media and other communication platforms. Public participation notices will be distributed throughout all monitoring and oversight stages of the Plan. Additionally, the Municipality will continue providing presentations to community groups regarding the LHMP and the status of mitigation strategy implementation. These groups may include elected officials, schools, and other community organizations. The Municipality will also promote civic engagement and preparedness education by offering training courses and workshops—such as Community Emergency Response Team (CERT) programs—and by informing residents about the National Flood Insurance Program (NFIP) and other relevant initiatives.

Mitigation efforts will be tailored to address the specific vulnerabilities and needs of individual communities, supporting the development of a more informed, prepared, and resilient population. This approach underlines the Municipality's commitment to sustained community engagement throughout the Plan's effective period, updating cycles, and post-adoption activities.

7.3 LHMP Oversight (D2-a)

The Municipality's strategy for Plan implementation, monitoring, and evaluation establishes a framework that promotes collaboration, information sharing, and innovation. Through its Planning Committee, composed of representatives from various municipal agencies and departments, the Municipality will work with partners and residents to apply a localized and coordinated approach to hazard mitigation. This collaborative strategy is intended to reduce losses, address community needs,

and strengthen the Municipality's capacity to withstand future hazard events.

The Plan will be monitored to assure:

- Maintain current and accurate hazard and risk information
- Ensure mitigation strategies reflect community and stakeholder priorities
- Comply with federal and Commonwealth LHMP requirements
- Maintain eligibility for mitigation funding
- Ensure consistency with other local and regional planning efforts

To support effective implementation, the Municipality will leverage existing resources and infrastructure planning processes. Mitigation actions identified as immediate or short-term will be pursued over the next five (5) years, subject to available funding and resources.

7.4 LHMP Evaluation and Monitoring

Evaluation of the LHMP will be an ongoing process. In addition to FEMA's required five-year review, the Municipality will conduct annual evaluations, or more frequently if conditions warrant. Following each annual review, the Planning Committee will meet to approve a yearly progress report documenting updates, accomplishments, and progress toward mitigation goals and objectives. This report will be submitted to the Office of the Mayor and made available to the public.

A preliminary schedule for Planning Committee meetings is outlined below:

Table 62. Preliminary Planning Committee Meeting Schedule

Time Period	Participants	Purpose of the Meeting
Annual Meeting (2027)	Planning Committee (Can be open to the public if deemed necessary)	The Committee will identify funding needs, reassess hazard priorities, develop strategies for grant applications, and conduct site visits to high-risk areas to monitor progress and engage directly with communities.
Annual Meeting (2028)	Planning Committee (Can be open to the public if deemed necessary)	The Committee will review mitigation implementation status, identify emerging

Time Period	Participants	Purpose of the Meeting
		risks, and evaluate community needs. Site visits will be conducted as necessary.
Annual Meeting (2029)	Planning Committee (Can be open to the public if deemed necessary)	The Committee will confirm progress on mitigation actions and assess the need for additional funding.
Annual Meeting (2030)	Planning Committee (Can be open to the public if deemed necessary)	The Committee will hold its final meeting prior to the next LHMP update to verify mitigation implementation status, which will be documented in the updated Plan.

7.5 LHMP Update and Revision (D2-c, D3-a)

7.5.1 Revision Following a Major Disaster

If a major emergency or disaster declaration affecting the Municipality occurs during the Plan's five-year term, the Planning Committee—along with stakeholders, community representatives, and nonprofit organizations—will convene to identify newly affected areas, revise mitigation priorities, and incorporate lessons learned. This meeting will replace the annual review scheduled for that year.

7.5.2 Five-Year Comprehensive Update

In accordance with federal guidance, the LHMP will be comprehensively updated five (5) years after approval and submitted to the State Hazard Mitigation Officer and FEMA for review and approval. Approximately eighteen (18) months prior to the Plan's expiration, the review process will begin, including a full evaluation of the municipal profile, risk assessment, and mitigation strategies, with attention to updated guidance and requirements.

7.6 Integration with Other Planning Mechanisms (D3-a)

The following public policies and planning documents were considered in the development of this LHMP:

Commonwealth Level:

- Puerto Rico Land Use Plan (PUT-PR)
- Aguada Territorial Plan (PT)
- Karst Special Planning Area Plan and Regulation
- Joint Regulation for the Evaluation and Issuance of Permits
- Special Flood Hazard Areas Regulation (2021)
- Stormwater System Design, Operation, and Maintenance Regulation
- Aguada Emergency Operations Plan

Following adoption, the LHMP will guide updates to the Territorial Plan, special area plans, and urban expansion plans, and will inform municipal budget priorities. Once FEMA approval is received, a digital copy of the Plan will be submitted to the Puerto Rico Planning Board to support updates to the PUT-PR and other relevant Commonwealth planning documents.

8. Adoption and Approval (F1-a, F1-b)

8.1 LHMP Adoption

Federal policy establishes LHMPs must include “Documentation that the LHMP has been formally adopted by the governing body of the jurisdiction requesting approval of the Plan. The municipality has one (1) year to adopt the Plan once it receives an *Approval Pending Adoption (APA)*.”¹⁶

This LHMP was adopted by the Municipality of Aguada on **XXXXXX**. A copy of **Resolution**, titled “*To Adopt the 2026 Natural Hazard Mitigation Plan of the Municipality of Aguada, and for Other Related Purposes,*” is included as part of **Appendix A**.

8.2 LHMP Approval

This LHMP was approved by FEMA and the SHMO on **XXXXXX**. A copy of the Approval Letter, titled “*Approval of the Local Hazard Mitigation Plan, Municipality of Aguada,*” is included in **Appendix A**. FEMA’s approval of the Plan is valid for a period of **five (5) years**, through **XXXXXX**

¹⁶ 44 C.F.R. §201.6(c)(5)

Selected References

Appendix A: Adoption and Approval

Adoption

Approval by FEMA

Appendix B: Planning Committee

Commitment Letter



Carta de Compromiso sobre el Plan de Mitigación Municipal

El Municipio de Aguada, representado en este acto por su alcalde, Hon. Christian Cortés Feliciano, mediante el presente documento denominado carta de compromiso se compromete en conjunto con la Junta de Planificación de Puerto Rico (JPPR) trabajar en la revisión y actualización del plan de mitigación contra peligros naturales municipal (Plan). El mismo tiene el objetivo de identificar actividades y medidas dirigidas a la mitigación de peligros naturales tales como huracanes, inundaciones, sequías, terremotos, deslizamientos, tsunamis entre otros que apliquen. El Plan tiene dentro de sus prioridades la reducción de pérdidas de vida y propiedad asociado a los diferentes peligros naturales e identificar medidas para atender las necesidades del municipio y sus residentes de manera planificada y ordenada, promoviendo así el desarrollo sostenido mediante la preservación de la función natural y los beneficios de la conservación de los recursos naturales y la infraestructura.

 Observando los planes que se han vencido, y están próximos a vencer, la *Oficina Central de Recuperación, Reconstrucción y Resiliencia* (COR3 por sus siglas en inglés) procedió asignar presupuesto a la JPPR para atender la revisión y actualización de los Planes de Mitigación Contra Peligros Naturales de los municipios. Es importante destacar que los planes de mitigación deberán estar aprobados por la Agencia Federal para el Manejo de Emergencias (FEMA por sus siglas en inglés) para evitar que los municipios pierdan los fondos asignados para la ejecución de los proyectos. Por lo tanto, recae sobre el municipio la responsabilidad de gestionar adecuadamente su plan, ya que la falta de vigencia conllevaría la pérdida de dichos fondos.

La JPPR está facultada para asistir a los municipios, conforme a la Ley Orgánica de la Junta de Planificación de Puerto Rico, Ley Núm. 75 del 24 de junio de 1975, según enmendada, 23 LPRA., sección 62 (k). Asimismo, la JPPR podrá hacer uso de recursos externos para la elaboración del plan de mitigación.

A su vez el Municipio está facultado a realizar acuerdos con cualquier agencia del Gobierno Central para que este desarrolle o lleve a cabo, en beneficio del Municipio, cualquier estudio, trabajo, obra o mejora pública municipal conforme a lo establecido en la ley Código Municipal de Puerto Rico, Ley Núm. 107 del 13 de agosto de 2020, según enmendada.

Es esencial que este plan cumpla con los requisitos del Acta de Mitigación de Desastre, la cual establece que los gobiernos municipales y estatales que hayan adoptado sus planes de mitigación contra peligros naturales serán elegibles para fondos de mitigación pre-desastre (Pre-disaster Mitigation Act) y post desastre a través del Programa de Subvención para la Mitigación de Riesgos (HMGP), el Predisaster Mitigation (PDM) y el Flood Mitigation Assistance Program (FMAP).

Por lo tanto, el municipio reconoce que la JPPR se comprometerá a coordinar junto al municipio la aprobación del Plan; coordinar la evaluación del Plan por parte del COR3 y FEMA; y efectuar la entrega del Plan aprobado por COR3 y FEMA al municipio.

Planning Committee Appointments



MUNICIPIO DE AGUADA

HON. CHRISTIAN E. CORTÉS FELICIANO
ALCALDE

OFICINA DEL ALCALDE

NOTIFICACIÓN DE DESIGNACIÓN

Comité de Planificación del Municipio de Aguada

Yo, Hon. Christian E. Cortés Feliciano, alcalde del Municipio de Aguada, designo a los siguientes funcionarios y representantes como integrantes del *Comité de Planificación para la actualización del Plan de Mitigación contra Peligros Naturales del Municipio de Aguada*, con el deber de apoyar, asesorar, coordinar y evaluar los trabajos de revisión, actualización, implementación y monitoreo del Plan mencionado.

Nombre	Puesto y Oficina	Correo electrónico	Teléfono (Ext.)
Wesley Vega López	Director Oficina de Planificación	wvega@aguada.gov.pr	(787)868-6400 ext. 1400
CPA Marisol Rosa Acevedo	Administradora Municipal	mrosa@aguada.gov.pr	(787)868-6400 ext. 1002
Jairo Jiménez	Ayud Administrativo – Manejo de Emergencias	jjimenez@aguada.gov.pr	(787)868-6400 ext. 2300
Jimmy Hernández L.	Comisionado de la Policía Municipal	policiamunicipal@aguada.gov.pr	(787)868-6400 ext. 2400
Javier Feliciano	Director de Obras Públicas	obraspublicas@aguada.gov.pr	(787)868-6400 ext. 2500
Hector Cajigas	Director de Control Ambiental	saneamiento@aguada.gov.pr	(787)868-6400 ext. 2601
Damaris Feliciano	Directora de Programas Federales	dfeliciano@aguada.gov.pr	(787)868-6400 ext. 1500
Carlos A. Rodríguez	Representante Comunidad	crodriguez@aguada.gov.pr	(787)868-6400 ext. 1807
Anibal Nieves	Representante Comunidad	No disponible	No disponible

Funciones principales del Comité:

- Coordinar con los trabajos relacionados con la actualización del Plan de Mitigación.
- Participar de talleres, presentaciones y reuniones sobre la actualización del Plan de Mitigación de Riesgos
- Proporcionar información, y datos sobre la evaluación de los riesgos y vulnerabilidades del municipio, así como las capacidades y los proyectos prioritarios de mitigación.
- Asegurar el cumplimiento con los requisitos estatales y federales para la elegibilidad de fondos de mitigación.

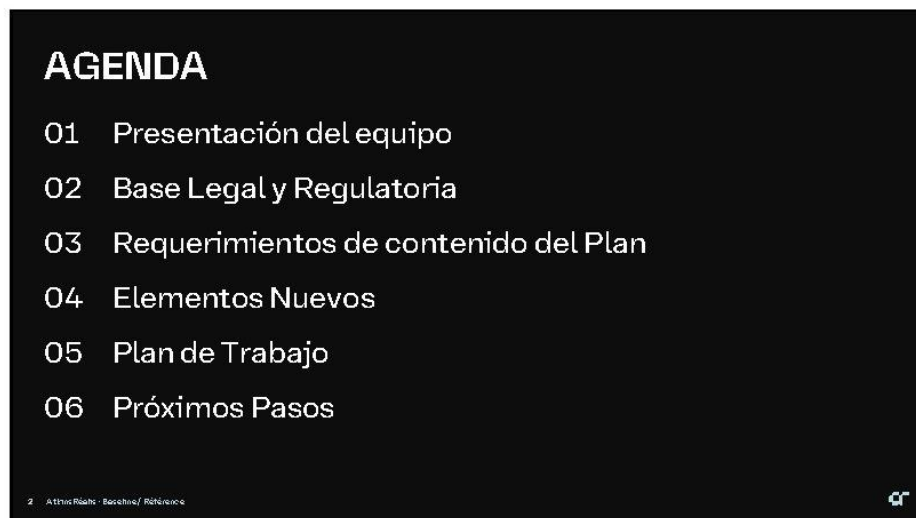
PO Box 517. Aguada, PR 00602 / Tel. 787-868-6400 / Fax 787-252-1561

First Planning Committee Meeting

Presentation

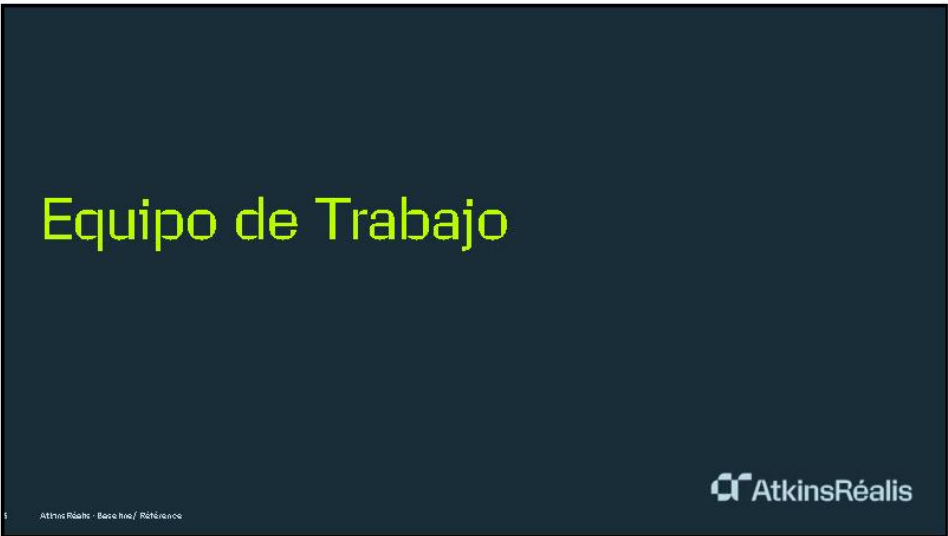


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Equipo de Trabajo

Mario González, Analista de Planificación

Yashira Santos, Analista de Planificación

Leonardo Pérez, Analista de Planificación

Armando Rodríguez, Analista de Planificación

Juan Rotger, Analista de Planificación

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Aguada

Mario González

Añasco

Leonardo Pérez

Isabela

Armando Rodríguez

San Germán

Yashira Santos

Rincón

Juan Rotger

6 Attya Róhm - Base hna / Rincón

6

Base Regulatoria

7 Attribución: Baseline/ Referencia



7

Base Legal y Regulatoria

- **Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), as amended**

- PL 100-707, signed into law November 23, 1988; amended the Disaster Relief Act of 1974, PL 93-288.
- National Flood Insurance Act of 1968, as amended.
- National Dam Safety Program Act (Pub. L. 92-367), as amended.
- Regulation: 44 CFR Part 201 Mitigation Planning.



8 Attribución: Baseline/ Referencia

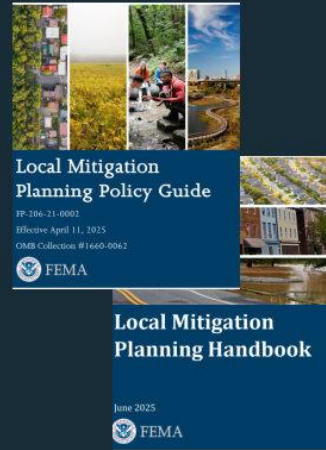


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Requerimientos del Plan de Mitigación

- Elemento A: Proceso de Planificación
- Elemento B: Identificación de Peligros y Evaluación de riesgos
- Elemento C: Estrategias de Mitigación
- Elemento D: Plan de Seguimiento e Implementación
- Elemento E: Actualización del Plan
- Elemento F: Adopción del Plan
- Elemento G: Peligros Potenciales ante fallos en Represas (opcional)
- Elemento H: Requisitos Estatales Adicionales



9 Atticus Rahn - Baschne/ Rahn/rahn

9

Elementos nuevos del Plan

- 1. Identificación y evaluación de riesgos**
 - Se clasifica la infraestructura crítica por servicio vital o línea de vida
 - Se analiza su exposición y vulnerabilidad
 - Se prioriza por línea de vida
- 2. Evaluación de capacidades**
 - Se evalúa la capacidad local para proteger servicios vitales
 - Se identifican brechas y se proponen acciones
- 3. Estrategia de Mitigación**
 - Se incluyen acciones específicas para proteger, estabilizar y restaurar servicios vitales
- 4. Participación de Partes Interesadas**
 - Se invita a agencias responsables o representantes de servicios vitales y se documenta su participación
 - Se comunica al público y recopila retroalimentación sobre los servicios vitales



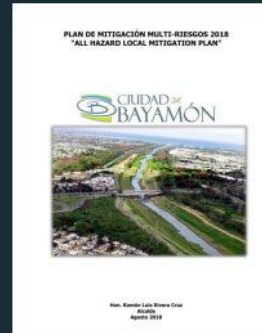
10 Atticus Rahn - Baschne/ Rahn/rahn

10

5

Elementos nuevos del Plan

- **Actualización del Plan:** "Review Tool" especifica los elementos que se deben documentar para reflejar los cambios
 - El Plan describe los cambios en las áreas propensas a peligros (ha incrementado o disminuido la vulnerabilidad o peligro)
 - Deberá reflejar los cambios en prioridades y progreso de los esfuerzos locales de mitigación.



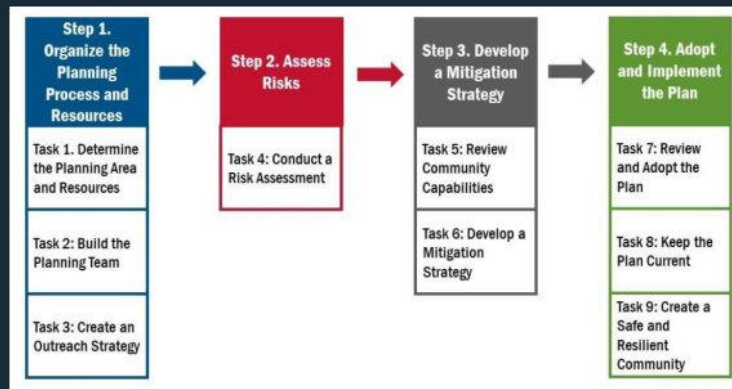
Element E: Plan Update		
Element E Requirements	Location in Plan (section and/or page number)	Met / Not Met
E1. Was the plan revised to reflect changes in development? (Requirement 44 CFR § 201.60(c)(3))		
E2-a. Does the plan describe the changes in development that have occurred in hazard-prone areas that have increased or decreased each community's vulnerability since the previous plan was approved?	Click or tap here to enter text.	Choose...

11 Athens-Roche - Baseline / Référence



11

Proceso del Plan de Mitigación



12 Athens-Roche - Baseline / Référence

[Local Mitigation Planning Handbook](#)


12

Riesgos a Evaluar

13 Athens Riads - Barcelona / Referência



13

Peligros a considerar

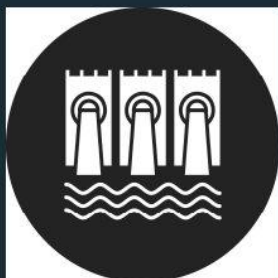
	Terremoto		Modificaciones costeras		Marejada Ciclónica		Fuego Forestal
	Deslizamientos		Inundaciones		Calor Extremo		Pandemia/ Epidemia
	Tsunami		Ciclones Tropicales		Sequías		

14 Athens Riads - Barcelona / Referência



14

Represas



Isabela

16 Altius Río de la Plata / Río de la Plata



15

¿Qué necesitamos del Municipio?



Designación del Comité de Planificación



Apoyo en la actualización de las estrategias de mitigación del plan anterior.



Incorporación de nuevas estrategias de mitigación.



Actualización de capacidades

16 Altius Río de la Plata / Río de la Plata



16

Evaluación de Capacidades

17 Attnis Róehr - Baseline / Referência



17

Capacidades



18 Attnis Róehr - Baseline / Referência



18

9

Participación Ciudadana

19 Attno Róalt - Baccine/ Róhúwice



19

Participación Ciudadana

- Dos reuniones de participación ciudadana.
- Notificación será publicada por Junta de Planificación.
- Publicar 15 días antes de la reunión
- Se otorga 15 días para comentarios
- Para la Segunda reunión se discute el primer borrador.
- El primer borrador será comentado por el público, el municipio y la Junta de Planificación



20 Attno Róalt - Baccine/ Róhúwice



20

10

Ventana para la primera actividad de participacion ciudadana

26 de febrero al 6 de marzo

Debe informar su fecha de reunion antes del lunes 9 de febrero.

Favor proveer varias fechas para que su analista de Planificación pueda estar.

De no recibir las fechas en o antes del lunes 9, su reunión será calendarizada después de las de otros municipios.



21 Attn: Róbal - Bachea / Róbal



21

Comunicación

22 Attn: Róbal - Bachea / Róbal



22

11



Información de Contacto

Programa	Junta de Planificación	prpb.lhmp@atkinsrealis.com
Plan Ivette Colón	Junta de Planificación	colon_i@jp.pr.gov
Plan William Pitre	AtkinsRéalis Caribe	William.Pitre@atkinsrealis.com /+19392051336

Pedimos que el título de todo correo comience únicamente con el nombre del municipio.
Ej.: "San Germán - Tablas de Mitigación Actualizadas"

Solicitamos que en todo correo electrónico relacionado con el programa se copie siempre al correo oficial:
prpb.lhmp@atkinsrealis.com

Atkins Réalis

23

Grupos de Trabajo

Atkins Réalis - Bahamas / République

24



25

Sign in Sheets



HOJA DE ASISTENCIA



Fecha: 5 de febrero de 2026

Hora: 1:30pm

Asunto: 1era Reunión -Revisión Plan de Mitigación contra Peligros Naturales

Nombre y dos apellidos	Teléfono	Municipio	Firma	Correo Electrónico
Wesley Vega López	Protected PII			wvega@aguarda.gov.pr

MINUTA

PROYECTO: PRPB 25 LHMP Update

TÍTULO: Primera Reunión con Comité de Planificación – Municipio de Aguada

LUGAR DE LA REUNIÓN: Centro de Gobierno
Roberto Sánchez Vilella, Sala de Prensa A y B, 300 Avenida José de Diego, San Juan, 00911, Puerto Rico

REUNIÓN: 1

FECHA Y HORA: 06/02/2026
1:00pm – 4:00pm

MINUTA POR: Mario González

Lista de Asistencia:

NOMBRE	INICIALES	COMPAÑÍA
Wesley Vega	WV	Municipio de Aguada, Director Oficina de Planificación Municipal (AGU)
Mario González	MG	AtkinsRéalis Caribe (ARC)
Rebecca de la Cruz	RdC	COR3
William Pitre	WP	AtkinsRéalis Caribe (ARC)
Ivette Colón	IC	Junta de Planificación de Puerto Rico (JPPR)

Asuntos Discutidos:

ID	ASUNTOS DISCUTIDOS
AD-1	Presentación e Introducción al Programa: La reunión comenzó con una presentación que proveyó el trasfondo y próximos pasos del Programa. La misma fue liderada por I. Colón y W. Pitre. Al finalizar la ponencia, el equipo de trabajo de ARC se dividió entre los municipios participantes para comenzar los talleres iniciales.

NOTA A LOS DESTINATARIOS:

Estas notas de la reunión reflejan la interpretación de AtkinsRéalis sobre la reunión y las acciones previstas que se derivan de la misma. Se asumirá su conformidad en que estas notas constituyen un registro fiel de lo discutido, a menos que se reciban comentarios adversos por escrito dentro de los cinco (5) días posteriores a su recepción.



ID	ASUNTOS DISCUTIDOS
AD-2	Actualización de Ejercicio de Priorización de Riesgos: El ejercicio de Priorización de Riesgo comenzó con una breve introducción entre el Punto de Contacto (POC por sus siglas en inglés) de AGU, W. Vega, y el facilitador de ARC- M. González. El ejercicio comenzó con un repaso de la priorización de riesgos en la versión previa del Plan de Mitigación del Municipio de Aguada. Entre los riesgos identificados como de mayor impacto se encontraban: Inundación, Licuación de terreno, Tsunami, Sequía y Vientos Fuertes. M. González presentó estos riesgos sobre el mapa del municipio provisto por la JPPR y solicitó a W. Vega discutir si el comportamiento de los mismos ha sido consistente en años recientes o si amerita una reclasificación de los riesgos. W. Vega comentó que el comportamiento de los riesgos se ha mantenido consistente, con la excepción de los deslizamientos y los incendios forestales. Explicó que la frecuencia e intensidad de los deslizamientos ha mermado significativamente en el período post-María. W. Vega comentó que en el 2023 ocurrió un fuego forestal significativo que se propagó entre los municipios de Aguada y Moca. Explicó que el incendio llegó a cubrir varias hectáreas, que en Aguada se registró la pérdida de dos (2) viviendas y que su control requirió la intervención de múltiples regiones del Cuerpo de Bomberos. W. Vega comentó que entre los riesgos que más consistentemente impactan al municipio, y/o que la preocupan con particularidad, son los de Inundación y Tsunami. W. Vega comentó que comunidades como Espinar, Tablonal y Carrizal son particularmente vulnerables a estos riesgos, cuentan con una sola ruta de acceso o escape. W. Vega comentó que entre los proyectos nuevos que le interesa incluir a la actualización del Plan se encuentra el estudio, diseño y construcción de rutas secundarias de acceso o escape para estas comunidades.
AD-3	Actualización de Tablas de las Estrategias de Mitigación M. González explicó que entre los elementos críticos de la actualización de los Planes de Mitigación, está la actualización de las Tablas de Estrategias de Mitigación identificadas o propuestas por el municipio en el plan anterior. M. González comentó que FEMA definió este ejercicio como un requisito para la aprobación de los Planes de Mitigación. M. González explicó que el tipo de narrativa para proveer una actualización debe ser precisa y fiel al estado corriente del proyecto. Añadió que, si se propone eliminar o añadir alguna estrategia, esta debe de incluirse en la tabla actualizada junto con una narrativa que justifique dicha acción. W. Vega indicó que se reunirá con el resto de su equipo para comenzar a trabajar con la actualización de las tablas.
AD-4	Ejercicio de Identificación de Necesidades Nuevas M. González explicó que uno de los objetivos del Programa es ayudar al municipio a definir una ruta para el desarrollo socioeconómico. Para ello, las estrategias de mitigación deben contemplarse no solo como mecanismos de protección ante riesgos existentes y futuros, si no también como herramienta para promover actividades más resilientes. M. González le preguntó a W. Vega sobre nuevas necesidades en proyectos de mitigación. W. Vega explicó que es prioritario para el municipio proveer rutas de desalojo para las comunidades de Espinar, Tablonal y Carrizal. Ambas partes concluyeron que esta necesidad podría definirse como de estudio, diseño y construcción de rutas alternas de acceso y desalojo para dichas comunidades. M. González aprovechó para repasar los "Lifelines" y

NOTA A LOS DESTINATARIOS:

Estas notas de la reunión reflejan la interpretación de AtkinsRéalis sobre la reunión y las acciones previstas que se derivan de la misma. Se asumirá su conformidad en que estas notas constituyen un registro fiel de lo discutido, a menos que se reciban comentarios adversos por escrito dentro de los cinco (5) días posteriores a su recepción.

ID	ASUNTOS DISCUTIDOS
	preguntó si algún otro elemento del municipio requiere atención. W. Vega comentó que el núcleo de servicios que incluye policía, bomberos, alcaldía y OMME cuenta con infraestructura física anticuada y vulnerable. Explicó que la planta física presenta problemas de suministro eléctrico y redundancia en sus sistemas. M. González sugirió como posible proyecto el diseño y construcción de un Centro de Mando ("Safe Room") que pueda operar de forma ininterrumpida durante una emergencia, propuesta que W. Vega acogió. R. de la Cruz preguntó a W. Vega si existe alguna otra parte del municipio que pudiera beneficiarse de un proyecto de mitigación. W. Vega indicó que va a discutir el tema con el resto del equipo de trabajo municipal.
AD-5	Discusión de Acciones por Tomar M. González recaló la importancia de que el municipio priorice la entrega de las Tablas de Estrategias de Mitigación. W. Vega indicó que comunicará lo discutido al resto del equipo y que estarán entregando las mismas a la brevedad posible.
AD-6	Coordinación de Primera Reunión Comunitaria M. González indicó que el municipio debe proveer dos fechas para la primera reunión comunitaria, así como la localización de la misma. W. Vega comentó que estará respondiendo a la JPPR con esta información a la mayor brevedad posible.

Acciones Por Tomar:

ID	ACCIONES POR TOMAR	FECHA LÍMITE	ENTIDAD RESPONSABLE
AT-1	Entrega de Tablas de Estrategias de Mitigación actualizada.	Sin definir, pero con carácter de urgencia.	Municipio de Aguada
AT-2	Confirmar fecha, lugar y hora para la primera reunión comunitaria.	09/02/2026	Municipio de Aguada

Acuerdos/Aclaraciones:

ID	DESCRIPCIÓN
AC-1	N/A

Anejos:

NOTA A LOS DESTINATARIOS:

Estas notas de la reunión reflejan la interpretación de AtkinsRéalis sobre la reunión y las acciones previstas que se derivan de la misma. Se asumirá su conformidad en que estas notas constituyen un registro fiel de lo discutido, a menos que se reciban comentarios adversos por escrito dentro de los cinco (5) días posteriores a su recepción.

ID	DESCRIPCIÓN ANEJO	NÚMERO DE PÁGINAS
AN-1	N/A	N/A

PRÓXIMA REUNIÓN:	Por definir.		
MEDIO DE DISTRIBUCIÓN:	Correo Electrónico.		
FECHA DISTRIBUCIÓN:	02/11/2026	ARCHIVO DE REFERENCIA:	First Planning Committee Meeting

NOTA A LOS DESTINATARIOS:

Estas notas de la reunión reflejan la interpretación de AtkinsRéalis sobre la reunión y las acciones previstas que se derivan de la misma. Se asumirá su conformidad en que estas notas constituyen un registro fiel de lo discutido, a menos que se reciban comentarios adversos por escrito dentro de los cinco (5) días posteriores a su recepción.

Public Notification

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*El Vacero de Puerto Rico no se responsabiliza por el contenido de anuncios pagados en esta sección.

Metro: 787-724-1485 / EMAIL: clasificados@elvocero.com



1^{RA} REUNIÓN DE PLANIFICACIÓN CON LA COMUNIDAD MUNICIPIO DE AGUADA

Asunto: Actualización del Plan de Mitigación contra Peligros Naturales
Lugar: Biblioteca Municipal
Fecha: 10 de marzo de 2026
Hora: 6:00 pm

NOTAS:

- Representante de la Junta de Planificación:
 - Plan. Ivette Colón Meléndez
- Personal enlace del Municipio de Aguada/Miembros del Comité de Planificación:
 - Wesley Vega López
 - Damaris Feliciano
 - Jimmy L. Hernández
 - Héctor Cajigas
 - Javier Feliciano
 - Carlos A. Rodríguez
 - Marisol Rosa
- Hon. Ramiro Javier Ariza Almanzar, Alcalde - Presente
- La reunión comenzó a las 6:00 pm.
- El Sr. Wesley Vega López, brindó el mensaje de bienvenida e introducción a la 1^{ra} Reunión de Planificación con la Comunidad (1^{ra} RPC). Además, mencionó los miembros del Comité de Planificación del municipio que estaban presentes en la reunión. Luego procedió a presentar al honorable alcalde Ramiro Javier Ariza Almanzar.
- El alcalde dio la bienvenida a los presentes, indicó la importancia de exponer a la comunidad información sobre el comienzo de la revisión y actualización del Plan de Mitigación, lo que significa esto para los proyectos financiados por la Agencia de Manejo de Emergencias Federal
- El Sr. Vega presentó a la Plan. Ivette Colón Meléndez, personal de la Junta de Planificación (JP), quien ofreció un resumen sobre los trabajos a realizarse en la 1^{ra} RPC, los cuales incluían la presentación sobre el proyecto, la encuesta a la comunidad y el ejercicio de identificación de los peligros naturales en su comunidad mediante los mapas impresos.
- La Plan. Colón procedió a brindar la presentación sobre el proceso de actualización del Plan de Mitigación contra Peligros Naturales del Municipio de Aguada. Entre los asuntos discutidos, se encuentran, pero no se limitan a los siguientes:
 - Se identificaron de fondos por COR3 y la JP para realizar la actualización de los planes de mitigación. A estos efectos, se identificaron aquellos planes con 5 años o más desde su aprobación, los cuales perdieron su vigencia y ahora forman parte de este proyecto de actualización.
 - Se mencionó el trasfondo normativo federal y los conceptos básicos de mitigación.

1 de 2

AtkinsRéalis - Baseline / Référence

- Se explicó el ciclo de manejo de emergencias (mitigación, preparación, respuesta y recuperación).
- Se orientó sobre el proceso de planificación para la mitigación.
- Se mencionó como se identificarán las estrategias de mitigación, esto mediante la evaluación de riesgos y evaluación de capacidades del Municipio.
- Se identificaron los riesgos naturales que se estarán evaluando a la luz de la realidad del Municipio. Además, se indicó que en reunión previa con el Comité de Planificación se solicitó a la JP que se incluyera el peligro por tornados.
- Se ilustró mapa con los 25 municipios cuyos planes de mitigación se están actualizando con la JP.
- Se discutió flujograma de las actividades que comprenden el proyecto de actualización de los planes de mitigación. Se identificaron las actividades realizadas y aquellas en el pipeline para realizar.
- Se administró una encuesta comunitaria mediante un código QR, lo que permitió a los participantes responder preguntas sobre los peligros identificados en su comunidad.
- Se exhortó a los asistentes a colaborar en un ejercicio de identificación de riesgos utilizando los mapas impresos provistos durante la actividad.
- El personal del Municipio y de la JP brindó asistencia a los participantes durante ambos ejercicios, ofreciendo orientación tanto en el uso de la encuesta como en la marcación de peligros en los mapas, pero los participantes no realizaron notas.
- Se le brindó oportunidad participación ciudadana durante el cual los asistentes manifestaron preocupación por el proyecto de Río Culebrinas y la información obsoleta utilizada por el Cuerpo de Ingenieros para el proyecto, que entienden que si se diseña bajo datos obtenidos en los setenta agravaría aún más las condiciones preexistentes, así como comunidades aledañas. También manifestaron su preocupación por las intenciones del municipio de Aguadilla de alterar un área natural que provocaría otros problemas a comunidades. Se les suministró los cuestionarios para que colocaran datos, ubicación y posibles problemas en los sectores que mencionan se pueden afectar por inundaciones.
- Una residente indicó que su propiedad se vio afectada por un tornado.
- Se entregó formulario para recopilar las preocupaciones.
- Se pasó al ejercicio de los mapas donde algunas personas marcaron la ubicación aproximada de sus residencias y sectores que pueden afectarse.
- Al concluir la presentación, se mostró la información de contacto de los enlaces de la JP relacionados con el Proyecto de actualización de los planes de mitigación, así como el correo electrónico oficial para canalizar comentarios (plandemitigacion@jp.pr.gov).
- La reunión comunitaria finalizó aproximadamente a las 8:00 pm.

Anejo: Notas del público y formularios cumplimentados.

10/mayo/2024

Primera reunión del Plan de Mitigación Aguada

- Incluir en el plan el tema de los tornados
- Han surgido cambios en los vientos, ahora son mas fuertes al punto de que se caen, arboles y postes ect.
- R: Se activa manejo de emergencia, no lo podemos controlar. Si existen informes o datos deben proveerlos para evaluación.

Ramonita Mendez y un grupo de personas expresan que el el BO. tablonal el Alcalde de Aguadilla Solicito al cuerpo de ingenieros una medida para el control de inundaciones por la construcción de 2 diques. Estos diques no se toma en consideración el sentir de la comunidad de tablonal y solo les incrementan las inundaciones. Las medidas que pretenden usar es que el Alcalde rehúye a las personas y apropiar sus propiedades. Esta solución que pretende hacer Aguadilla no aporta solución, si no que perjudica a los residentes de tablonal. Este proyecto pone en riesgo a toda la comunidad.

BOLETA DE COMENTARIOS COMUNITARIOS

Plan de Mitigación contra Peligros Naturales Aguada
Municipio

Nombre (Opcional): Olga C. Vega Pérez (787-450-1829)

Barrio: Espinar

Sector: _____

Carretera y Kilómetro: 442 Km 1.0

Referencia relativa del lugar: Carretera principal

Comentario relacionado a temas de mitigación de peligros naturales:

(Describe inquietudes, riesgos identificados, sugerencias o situaciones que afecten su comunidad)

Nuestra comunidad es costera y el río Piedras es parte de nuestro territorio. Es una comunidad que requiere un plan de mitigación.

¿Cómo se afectó?

Después de las inundaciones del Huracán María nuestra comunidad estuvo bien afectada. El daño quedó irreparablemente en las tierras al mar, río Piedras y Ciénaga de María.

Fecha: 10/3/2024

Procedi-
Sustar (Coles y Panes)

- Con proyectos de mitigación
- Altopos sinidra de idolo y mangla.
- No opayones construción de diques.
- Estra construcciones en la costa.
- Construir proyectos que afectan el
- avar.
- Construir drenajes en el
- Valle del Coloso.
- La labor del municipio con el mantenimiento
- y limpieza de alcantarillas, quebrados, etc.
- Los rios corrientes y se debe mejorar.
- En el 2024 el cuerpo de ingenieros
- quedó en la vía al estudio hidrológico
- Para hacer mejoras resultados.

COMENTARIOS DE LA COMUNIDAD

Plan de Mitigación contra Peligros Naturales

Aguada
Municipio

Nombre (Opcional): _____

Barrio: Aguada

Sector: _____

Carretera y Kilómetro: _____

Referencia relativa del lugar: _____

Comentario relacionado a temas de mitigación de peligros naturales:

(Describa inquietudes, riesgos identificados, sugerencias o situaciones que afecten su comunidad)

* Mayor inquietudes tienen que ver con la inacción respecto a construcciones en nuestra costa. la Restauración de áreas naturales es esencial. Esto incluye remoción de escombros en la costa.

¿Cómo se afectó?

* Me preocupa la propuesta de un proyecto turístico en Bo. Río Grande

* Los adultos mayores en Espinar necesitan que se rescate la escuelita para un centro comunal que sirva de centro de acopio, comedor, cisternas, equipo médico, etc.

* Mayor vigilancia y protección de caños, ríos y quebradas. ^{los ríos} Se necesita un equipo para trabajar en esto.

* Estructura desabajo vertical

En el Plan de Recuperación, p.41
Iniciativa A.2-Plan de Trabajo para limpiar y conservar cuerpos de agua.
"se recomienda restaurar la faja de conservación de 5mts requerida por la Ley # 49 de 2003..."

Fecha: _____

* Se debe insistir en revisar el lenguaje del Plan para que no se le de prioridad a infraestructura gris, (muros de contención, diques, represas) si se puede explorar y trabajar con infraestructura verde.

Además, integrar a la comunidad en estos procesos.
página 234 - Plan Mitigación 2020

* Formalizar la Reserva del Caño Madre Vieja como medida de Mitigación. (pág. 234)

COMENTARIOS DE LA COMUNIDAD

Plan de Mitigación contra Peligros Naturales Aguada
Municipio

Nombre (Opcional): Maria E. Ruiz Fierro

Barrio: Bo. Piedras Blancas

Sector: Sector Paseo Las Flores Calle Clavel Casaderrampa

Carretera y Kilómetro: Carr. 411 Km. 2.2 Int. Aguada, P.R.

Referencia relativa del lugar: frente al Sr. Jelis César Zomán (Don Jelis) ex-alcalde

Comentario relacionado a temas de mitigación de peligros naturales:
(Describe inquietudes, riesgos identificados, sugerencias o situaciones que afecten su comunidad)

① Inquietud de que vuelva a surgir otro tornado en el área del Paseo Las Flores y no lleguen las ayudas ni nos cubra los seguros de póliza de la casa.

② Inquietud por una quebrada que ha sido tapada con tierra y venga un huracán o fuertes lluvias que inunden el área de las casas dentro del Paseo Las Flores

¿Cómo se afectó?

① Dentro del tornado que vimos formarse la presión del aire fue tan fuerte que se levantaron las locetas de la malgucina. Ninguna agencia se preocupó por el seguro de la propiedad ni nos quiso cubrir.

② Ante el azote del huracán María se inundó la quebrada y estuvo cerca de llegar al patio trasero de las casas en el área de la Calle Clavel.

Fecha: 10 de marzo 2026
-martes-

Maria E. Ruiz Fierro
787-314-5770

COMENTARIOS DE LA COMUNIDAD

Plan de Mitigación contra Peligros Naturales Aguada
Municipio

Nombre (Opcional): Javier López Vázquez (Cel. 939-349-3293)

Barrio: Espino

Sector: Costero (Zona Marino Teniente)

Carretera y Kilómetro: (ZMT)

Referencia relativa del lugar: Zona Marítimo Terrestre del Bo. Espino de Aguada

Comentario relacionado a temas de mitigación de peligros naturales:
(Describe inquietudes, riesgos identificados, sugerencias o situaciones que afecten su comunidad)

Siembre de Abals y reforestación del marabón, imajen en los terrenos públicos que conforman la ZMT (Reserva Natural del Cabo Macho Viejo). Peseamos que se apruebe su designación como reserva por parte de la JPPR. El municipio de Aguada se apoya y entiende que la conservación de estos terrenos ayuda a combatir o reducir la erosión.

¿Cómo se afectó? Seguridad de los muestreos en los puntos bajos del Bo. Espino de Aguada.

Actualmente estamos a la espera que la JPPR realice las vistas públicas y se establezca de una vez este Reserva Natural que conforma el Segmento de Barrera Costera → PR-75 y PR. 75P → (Parque Colón)

COMENTARIOS DE LA COMUNIDAD

Plan de Mitigación contra Peligros Naturales Aguada
Municipio

Nombre (Opcional): Ramonita Méndez Méndez

Barrio: Tabernales (Carrizales)

Sector: Tablonal

Carretera y Kilómetro: Car. 439-Int. 4441

Referencia relativa del lugar: _____

Comentario relacionado a temas de mitigación de peligros naturales:

(Describe inquietudes, riesgos identificados, sugerencias o situaciones que afecten su comunidad)

En Bo. Espinar de Aguada y Victoria de Aguadilla, el NSACE ha presentado proyecto de control de inundaciones con 2 diques, sin considerar a Tablonal, a quien le ofrecen desalojo y rehabilitación, imponiendo al Alcalde de Aguada expropiación. Si alguna medida se haga en forma natural.

¿Cómo se afectó? Esta en estudios H.H. Proyecto esta activo.

Fecha: _____

COMENTARIOS DE LA COMUNIDAD

Plan de Mitigación contra Peligros Naturales Aguada
Municipio

Nombre (Opcional): _____

Barrio: Esperal

Sector: La playa

Carretera y Kilómetro: PR 442 Km. 1.8

Referencia relativa del lugar: _____

Comentario relacionado a temas de mitigación de peligros naturales:

(Describe inquietudes, riesgos identificados, sugerencias o situaciones que afecten su comunidad)

Caso Michi Vieja - Puma Natural - Caseros de Agua
Indígena de Puma
Mitigación de los manglares
Control de tormentas

¿Cómo se afectó?

Visión afectó la propiedad - Todo zinc

Fecha: 10 de marzo de 2026

TRASFONDO

Ley de Mitigación de Desastres de 2000 (DMA2K)

Requiere un plan de mitigación aprobado y adoptado para recibir financiamiento federal a través de:

- ☐ Programa de subvenciones para mitigación de peligros
- ☐ mitigación previa al desastre, y
- ☐ asistencia para mitigar inundaciones.

(d) **Local governments.** The key responsibilities of local governments are to:

- (1) Prepare and adopt a jurisdiction-wide natural hazard mitigation plan as a condition of receiving project grant funds under the HMGP, in accordance with § 201.6.
- (2) At a minimum, review and update the local mitigation plan every 5 years from date of plan approval of the previous plan in order to continue program eligibility.

Regulation: 44 CFR Part 201 Mitigation Planning.



PLANES DE MITIGACIÓN
CONTRA PELIGROS NATURALES
Planificar para proteger

CONCEPTOS IMPORTANTES

Peligros naturales	Eventos o sucesos naturales que amenazan vidas, bienes materiales, infraestructura, el ambiente y otros activos. Tienden a ocurrir repetidamente en las mismas zonas geográficas. Ej. Terremotos, deslizamientos de tierra, hundimientos, Inundaciones, tsunamis, huracanes, erosión, incendios, etc.
Mitigación de riesgos	Esfuerzo o acciones para reducir la pérdida de vida y propiedad reduciendo el impacto de los peligros naturales.
Plan de mitigación contra peligros naturales	Documento donde se evalúan la vulnerabilidad del municipio ante los peligros naturales y se identifican acciones para minimizar las pérdidas de vida y propiedad ante un evento futuro.



PLANES DE MITIGACIÓN
CONTRA PELIGROS NATURALES
Planificar para proteger

CICLO PARA EL MANEJO DE EMERGENCIAS



PROCESO DE PLANIFICACIÓN PARA LA MITIGACIÓN

1. Coordinación con Municipio
2. Evaluación de riesgos
3. Evaluación de capacidad
4. Estrategias de mitigación
5. Mantenimiento del plan
6. Documentación del plan



COORDINACIÓN CON MUNICIPIO

- Carta de compromiso
- Designar el Comité de Planificación de Mitigación de Peligros del municipio.
- Reunión inicial (“kick off meeting”).
- La participación pública y divulgación a las principales partes interesadas.
- La recopilación y el análisis de datos.
- Preparación y presentación del plan.

EVALUACIÓN DE RIESGOS



Terremoto



Erosión costera/
modificaciones
costeras



Marejada
Ciclónica



Deslizamientos



Inundaciones



Calor Extremo



Tsunami



Ciclones Tropicales



Sequías



Fuego Forestal



Pandemia/
Epidemia

EVALUACIÓN DE CAPACIDAD

- Mide la capacidad para implementar el plan de mitigación de peligros.
- El propósito es establecer la capacidad municipal para la planificación, determinación de la capacidad financiera, la asistencia técnica y la necesidad de adiestramiento.
- Las capacidades evaluadas son las siguientes:



RESULTADO DE EVALUACIÓN



ESTRATEGIAS DE MITIGACIÓN

- Describir las metas y objetivos específicos para minimizar el impacto en el municipio.
- Identificar acciones de mitigación específicas y proyectos.
- Estas pueden incluir:
 - **Prevención**– actividades tales como planificación usos terrenos, regulaciones, mantenimientos, etc.
 - **Protección de propiedades**– mejoras de diseños, relocalización, adquisición, etc.
 - **Proyectos de estructura**– ej. Diques, muros de contención, alcantarillado pluvial, etc.
 - **Servicios de emergencia**– alertas, sistemas de advertencias, manejo y planes de desalojo, ejercicios de respuesta a emergencias, etc.
- Educación y concientización pública.



MANTENIMIENTO Y DOCUMENTACIÓN DEL PLAN

- **Monitoreo:** Identificar frecuencia para verificar el progreso de las acciones en el plan.
- **Evaluación:** Determinar si el plan sigue siendo viable, si las acciones aún tienen sentido, etc.
- **Actualización:** Si se determina que algo debe cambiarse en el proceso de evaluación, identificar persona a cargo (comité de planificación) para la actualización cada 5 años.
- **Adopción del Plan por el municipio:** ordenanza de la legislatura municipal u orden ejecutiva del alcalde.
- Revisión, certificación y aprobación de FEMA.

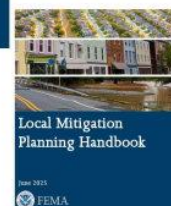
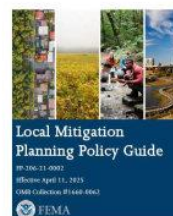


PROYECTO ACTUALIZACIÓN DE LOS PLANES DE MITIGACIÓN



ALCANCE DEL TRABAJO

1. Revisar y actualizar los planes de mitigación contra peligros naturales de acuerdo con las nuevas guías y regulaciones.
2. Coordinar las actividades y trabajos en conjunto con el municipio y la Junta de Planificación.
3. Promover la participación ciudadana.
 - Reuniones de planificación con la comunidad
 - Página cibernética JP (www.jp.pr.gov)



ACTIVIDADES DEL PROYECTO



ENCUESTA DE LA COMUNIDAD





IDENTIFICAR ÁREAS DE RIESGO







¡GRACIAS!

INFORMACIÓN DE CONTACTO

Lcdo. Héctor Morales Martínez
Presidente

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Directora Ejecutiva Auxiliar Interna
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plandemitigacion@jp.pr.gov
*Incluir nombre del municipio en el asunto.

787-723-6200 ext. 16623 y 16681







MUNICIPIO DE AGUADA
HON. CHRISTIAN E. CORTÉS FELICIANO
ALCALDE

OFICINA DE PLANIFICACIÓN

HOJA DE ASISTENCIA
PRIMERA REUNION COMUNITARIA PLAN DE MITIGACION
3 de marzo de 2026

NOMBRE	AGENCIA/BARRRIO	TELEFONO	CORREO ELECTRONICO	FIRMA	COMENTARIOS
Dannaris Feliciano Nieves	Mun Aguada	Protected PII	Protected PII	Protected PII	comite
Olga C. Vega	Espinar				
Juan I. Muñoz Morales	Espinar				
Adrián Rodríguez Millares	Mun Aguada				comite
Christina Cortés	Mun Aguada				
Jimmy Hernández	Mun Aguada				comite
Wesley Vega Jop	Mun Aguada				comite
Hector L. Carraz	Mun Aguada				comite
Israel S. Vago Estro	Alcalde				
- María E. Ruiz Furió	Iglesia Protestante de Aguada				

PO Box 517, Aguada, PR 00602 / Tel. 787-868-6400 / Fax 787-252-1561



MUNICIPIO DE AGUADA
HON. CHRISTIAN E. CORTÉS FELICIANO
ALCALDE

OFICINA DE PLANIFICACIÓN

- Mariela Rosa Aguado	Mun. Aguada	Protected PII	Protected PII	Protected PII	comite
- Edwin Aguado River	Iglesia Protestante de Aguada				
Yonixsa M. Ovea	Mun Aguada				
Ramona Rincón	Tablante Aguada				
Vergel López Nieves	Mun Aguada				
Mauricio Ponce	Malpaso				
José Feliciano	Aguada Mayor				comite
Javier López Vázquez	Aguada, Malpaso				

PO Box 517, Aguada, PR 00602 / Tel. 787-868-6400 / Fax 787-252-1561

Photographic Documentation



Second Public Participation Meeting

Public Notification

Minutes

Presentation

Sign in Sheets

Photographic Documentation

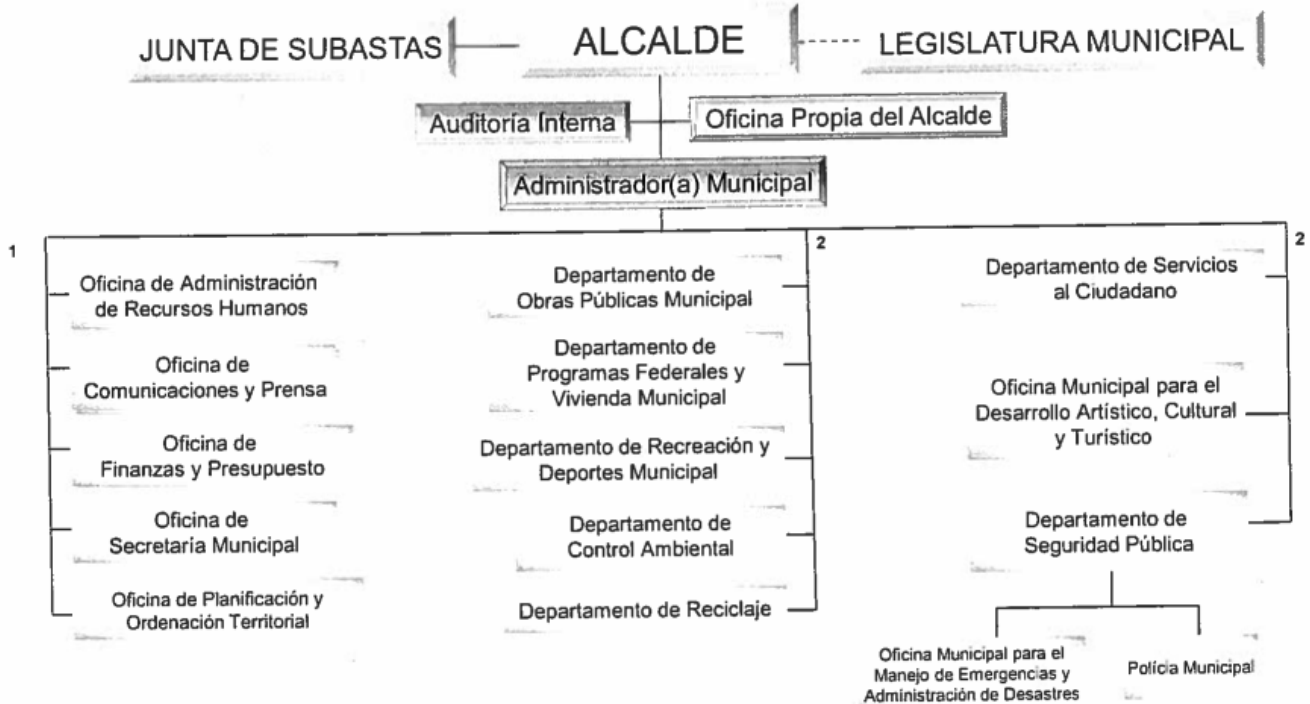
Other Outreach Activities

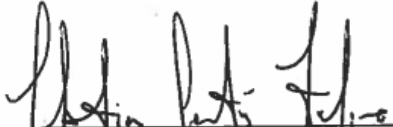
Appendix D: Stakeholder Involvement

Appendix E: Municipality Org Charts

Estado Libre Asociado de Puerto Rico
Gobierno Municipal de Aguada

ORGANIGRAMA

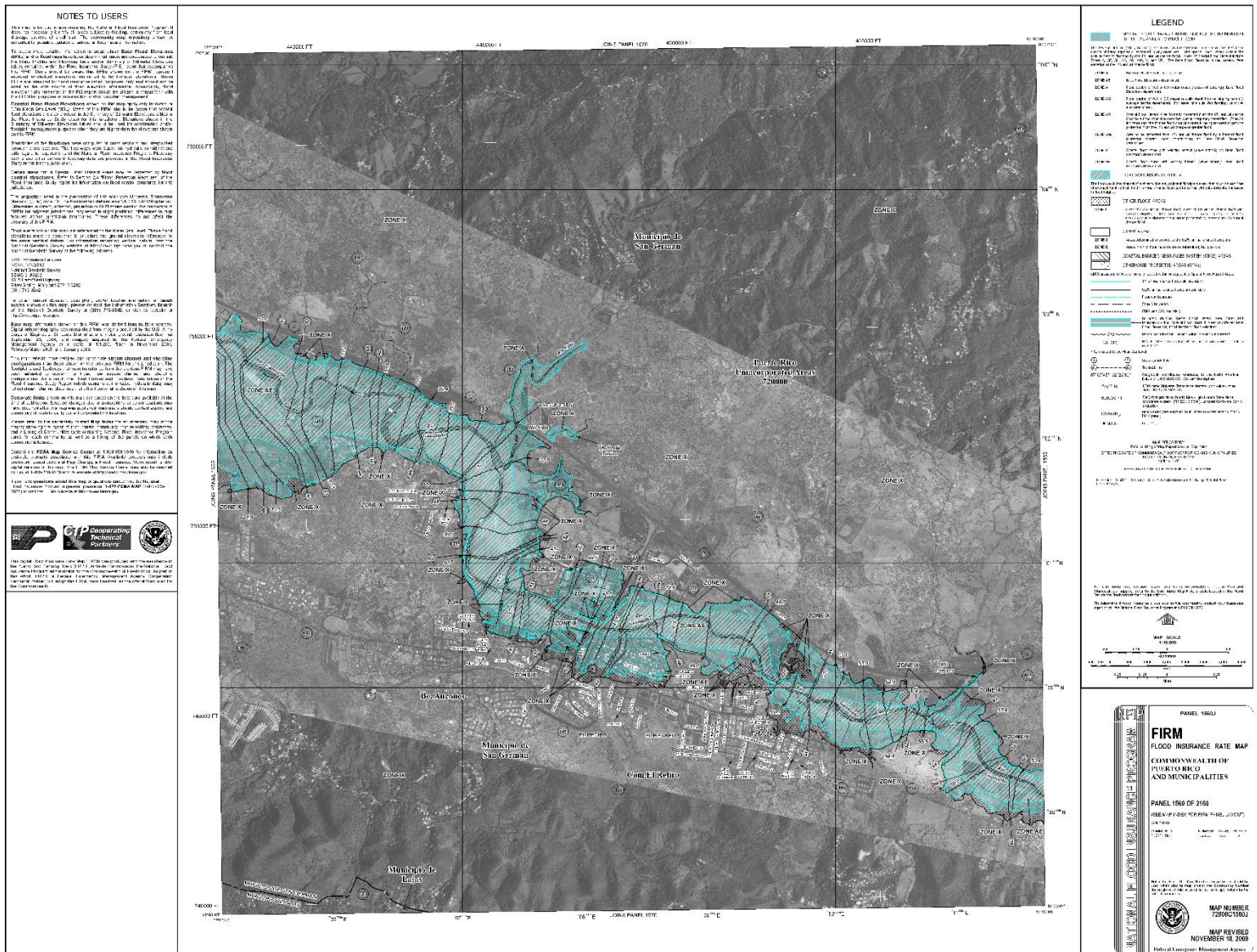



Hon. Christian E. Cortés Feliciano
Alcalde

19/enero/2021
Fecha

* Oficinas de Apoyo y Asesoramiento
• Departamentos Operacionales

Appendix F: Other maps for reference



Appendix G: Historical List of Tropical Cyclone Events

Up to 1989 (Hurricane Hugo) there were a total of 102 tropical cyclones recorded to have made landfall or that got close enough to the Island to create significant damages (Quiñones, 1992). Adding to those the tropical cyclones that have made landfall or created significant damage in Puerto Rico since 1989, we find that there has been a total of 117 recorded tropical cyclone that have affected Puerto Rico since the Spanish colonization begun in 1502. Below there is a brief description of some of those cyclones and their impact on the Island.

- **Fiona: September 17–21, 2022 (Hurricane Cat 1)** – Hurricane Fiona made landfall along the southwest coast of Puerto Rico near Punta Tocón at 3:20 p.m. with winds up to 85 mph, according to the National Hurricane Center. It caused the threat of catastrophic flooding, river overflow, and landslides, as well as the collapse of the electrical system.
- **Laura: August 22, 2020 (Tropical Storm)** – Tropical system Laura impacted the Island with heavy rain and strong winds, causing severe flooding particularly in central and western Puerto Rico.
- **Isaias: July 29–30, 2020 (Tropical Storm)** – Isaias produced heavy rainfall and strong winds across most municipalities of Puerto Rico.
- **María: September 20, 2017 (Hurricane Cat 4)** – The eye of the hurricane entered Puerto Rico at 6:15 a.m. through Yabucoa with winds of 155 mph, crossed the Island diagonally, and exited near 2:00 p.m. between Barceloneta and Arecibo at 109 mph. The phenomenon battered the Island with wind and rain for more than 30 hours. The electrical system was destroyed, transmission lines were down, and 80% of utility poles were knocked down, leaving the Island in darkness. Puerto Rico also lacked potable water service because it depends on electricity for operation. Additionally, 95% of cellular communication was out of service.
- **Irma: September 5, 2017 (Hurricane Cat 4)** – Although Irma did not make direct landfall on the main island, it impacted on the municipality island of Culebra, where it destroyed 30 homes and cut off communication by damaging the only communication tower. For Puerto Rico overall, between 25% and 30% of plantain, banana, papaya, and coffee farms were destroyed. Irma represented a \$30.6 million loss for farmers across Puerto Rico. Approximately 6,200 people had to seek shelter. PREPA reported that a total of 1.1 million customers lost power due

to the hurricane. PRASA reported that at least 362,000 customers were without potable water service.

- **Irene: August 22, 2011(Tropical Storm)** – Total rainfall reached 22 inches over 3 days, with the eastern area most affected—the same area that had received over 6 inches earlier in August from the close passage of Tropical Storm Emily. The Río Grande de Manatí in Manatí reached its third-highest level in history. Flooding in the Río Puerto Nuevo at Hato Rey reached its fourth-highest record level. There was one direct death due to drowning and \$500 million in losses.
- **Emily: August 3, 2011 (Tropical Storm)** – Winds from this tropical storm left approximately 18,500 PREPA customers without electricity and nearly 6,000 customers without potable water service. Rainfall associated with this system reached 10 inches, causing several rivers to overflow their banks.
- **Jeanne October 3, 2004 (Tropical Storm)** – Maximum winds reached 72 mph; due to heavy rain, 3,629 people were evacuated. Schools, residences, and commercial buildings suffered damage, and 302 roads were closed due to landslides and debris.
- **Dean: September 21, 2001 (Tropical Storm)** – Although its highest winds were estimated at 165 mph, in Puerto Rico it only caused about \$2 million in damage due to flooding.
- **September 21–22, 1998 Georges (Hurricane Cat. 3)**
An intense hurricane that crossed Puerto Rico, entering from the east near Humacao and exiting through Cabo Rojo. Georges produced winds of 115 mph and flooding throughout Puerto Rico. More than 72,000 homes in Puerto Rico were damaged, and 28,000 were completely destroyed.
- **September 9–10, 1996 Hortense (Hurricane Cat. 1)**
Hortense entered through Guayanilla in southern Puerto Rico and exited through Mayagüez. The greatest damage was caused by flooding and landslides, which resulted in the deaths of 18 people. Agricultural losses were estimated at about \$127 million.
- **September 16, 1995 | Marilyn | Hurricane | 2**
Landslides and flooding were the main impacts left in its wake, with winds of approximately 110 mph. The municipal islands of Vieques and Culebra were the most affected.
- **September 18, 1989 | Hugo | Hurricane | 4**
The eye of the hurricane passed over the island of Vieques and then over the northeastern tip of Puerto Rico. Maximum winds from Hugo were estimated at 140 mph, and rainfall totaled 9.20 inches.
- **November 7, 1984 | Klaus | Tropical Storm | N/A**
The strongest winds from Klaus remained offshore. The maximum winds

recorded at the Roosevelt Roads Naval Base were 37 mph. The southern half of Puerto Rico registered approximately 7 inches of rain, while Culebra recorded 10 inches.

- **September 4, 1979 | Frederic | Tropical Storm | N/A**
Just five days after Hurricane David passed south of Puerto Rico, the Island faced the threat and direct impact of Tropical Storm Frederic (known locally as Federico). Following nearly the same path as David but as a weaker system, Frederic's rains compounded previous flooding. Damage caused by rain and flooding resulted in losses of \$125 million.
- **August 30, 1979 | David | Hurricane | 4**
Passed 90 miles from Ponce and 70 miles south of Cabo Rojo, with winds of approximately 175 mph, destroying more than 800 homes and causing \$55 million in agricultural losses.
- **September 15–16, 1975 | Eloise | Tropical Storm | N/A**
The heaviest rains and highest death toll were recorded between Guayanilla and Mayagüez. Rainfall data shows maximum precipitation occurred in Dos Bocas, Utuado, with 33.29 inches over three days. Resulting flash floods caused 34 deaths and over \$60 million in damage. Deaths were due to drowning, a collapsed building, electrocution, and one person burned in an electrical fire at a refinery. Hundreds were injured, and more than 6,000 people were evacuated.
- **September 5–6, 1960 | San Lorenzo (Donna) | Hurricane | 3–4**
Wind impact on the Island was minimal, but rainfall was massive across the eastern half of Puerto Rico. This was one of the most significant flooding events in Puerto Rico's history. Nearly all rivers east of the Río Grande de Manatí overflowed, causing destruction. The event killed about 107 people by drowning, left 30 missing, destroyed 519 homes, and damaged 3,762 homes, according to the Red Cross. The greatest tragedy occurred in Humacao when river flooding swept through town streets and homes. Damage included bridges, utilities, agriculture, rail systems, and was estimated at over \$7 million. More than 10 inches of rain fell across much of eastern Puerto Rico in 6–8 hours, with peaks of 15–20 inches starting the night of September 5. Flooding in the Humacao, Turabo, and Valenciano rivers rank among the highest in history. September 1960 was extremely rainy, and flood evaluation had to be accelerated because rain erased flood marks.
- **September 12, 1956 | Santa Clara (Betsy) | Hurricane | 1**
Hurricane Santa Clara, also known as Betsy, entered through Maunabo and Patillas, crossed Puerto Rico east to west, and exited between Camuy and Hatillo. It caused 16 deaths, 24 injuries, and estimated losses of \$25.5 million.

Gusts reached up to 115 mph at Ramey Air Base in Aguadilla. In San Juan, sustained winds were 73 mph with gusts up to 92 mph.

- **September 26–27, 1932 | San Ciprián | Hurricane | 3**
A destructive hurricane that entered through Ceiba, crossed Puerto Rico, and exited through Aguadilla with estimated winds of 120 mph. San Ciprián caused 225 deaths and \$30 million in damages. Average rainfall recorded in Maricao was 16.70 inches.
- **September 13, 1928 | San Felipe II (Okeechobee Hurricane) | Hurricane | 5**
A devastating hurricane that entered through Guayama, crossed the Island from southeast to northwest, and exited between Aguadilla and Isabela with winds over 160 mph. San Felipe II caused \$50 million in losses and 300 deaths.
- **August 2, 1899 | San Ciriaco (The Puerto Rico Hurricane of 1899) | Hurricane | 4**
San Ciriaco caused catastrophic damage during its passage through Puerto Rico and was the first hurricane under U.S. rule. Nearly 250,000 people were left without shelter and food. Damages were estimated at \$35,889,013, mostly agricultural losses, especially coffee crops. Utuado was the most impacted municipality, with losses reaching \$5 million. It is estimated that around 3,100 to 3,369 people perished.
- October 29, 1867 San Narciso Hurricane Cat. 3
- Hurricane **San Narciso** struck Puerto Rico on **October 29, 1867**, and is regarded by modern reanalysis as a **Category 3 major hurricane**, with estimated sustained winds of about **125 mph**. The storm caused **widespread destruction across the island**, severely damaging homes, agriculture, and infrastructure during a time when no forecasting or organized emergency response existed. San Narciso is also remembered for its place in history, as it occurred just weeks before the **1867 Virgin Islands earthquake and tsunami**, making that year one of the most catastrophic periods of the 19th century in Puerto Rico.
- **August 16, 1508 | San Roque | Tropical Storm | N/A**
The first recorded cyclone in Puerto Rico. Reported by Juan Ponce de León, whose caravel was stranded on the shore by strong winds and rough seas. It affected the southwestern area between Guayanilla and Guánica.